# Relational modelling

## Database structure

* Data is organized in database in the form of tables as rows and columns
* Constraints define how data is saved
* Entities are essential building blocks in database. It is a basic object with independent existence.
* An entity instance is a single occurrence of an entity
* Attributes provide information for each entity. i.e, it describes the characteristics or additional details about the entity.

## Normalization

* Formal technique for analyzing a relation based on its primary key and functional dependencies between its attributes.

**Goal**: reduce redundancy, reduce anomalies

* As normalization proceeds, relations become progressively more restricted (stronger) in format and also less vulnerable to insert/update/delete anomalies

## Relationships

Meaningful business associations.

### Multiplicity

* Cardinality - maximum number of possible relationship occurrences for an entity
* Participation - optional or mandatory

### Types of relations

There are 3 different types of relations in the database:

* one-to-one
* one-to-many, and
* many-to-many

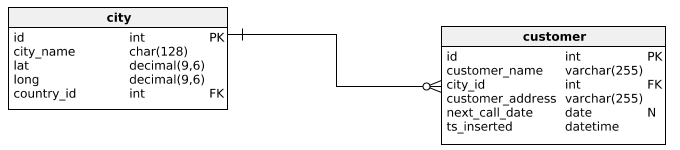
### One-to-many relation

It’s the most commonly used and the remaining two are “subtypes” of this one. Let’s start with a real-life problem.

**Example**

Imagine that we want to store a list of all our customers in the database. For each customer, we also want to store the city where this customer is located, and we know that the customer will be in exactly one city.

This the typical example of one-to-many relation and this is how we solved it in our model:



We simply established a relation from the **city.id** to **customer.city\_id**. And this works, because the customer can be only in one city and the city could have many different customers located in it.

When you want to determine the nature of the relation you need to establish between two tables just do this. In our example – For **one** city, we could have **many** different customers located in it. And the other way around – For **one** customer, we can have only **one** city it’s located in.

So, how to choose between these 3 different types of relations? If you said the word “many” only once, then this is one-to-many relation. If you would use the word “many” two times, the relation would be many-to-many. And if you wouldn’t use it at all, then it would be one-to-one.

**Tip**: put the primary key of one side as a FK in the many side table.

### **Many-to-many relation**

The second out of three types of relations is a many-to-many type. This type is used when both tables could have multiple rows on the other side. Let’s see an example.

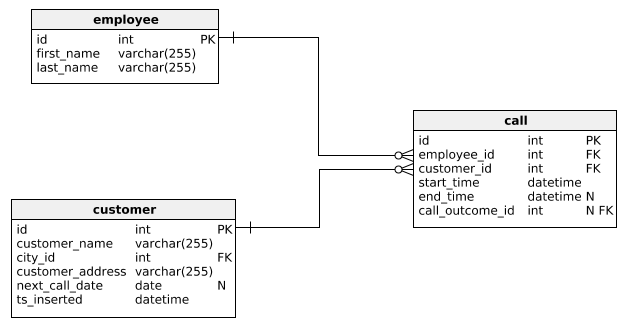
**Example**

We need to store calls between employees and customers.

**One** employee, during the time, could call **many** customers. Also, **one** customer, during the time, could receive calls from **many** employees.

Notice that we’ve mentioned the word “many” two times. This is the signal we need to resolve this using many-to-many relation (out of 3 types of relations we have on disposal). To solve it we’ll create an associative entity as follows:

* Add a table between tables **employee** and **customer**
* Add foreign keys (**employee\_id** & **customer\_id**) to that new table (**call**)



Now, when we look from the employee perspective, **one** employee could make **many** (multiple) calls. On the other hand, **one** customer could be related to **many** (multiple) calls. Therefore, many-to-many relation is implemented with adding a new table and one-to-many relations from both sides.

### **One-to-one relation**

Compared to previously mentioned types of relations, this one is really rarely used. Let’s go with an example.

**Example**

In the database, we want to store employees, but also their valid identity cards. We’re not interested in storing any other types of documents or identity cards that were previously valid, so we need exactly 1 (or none) identity card for 1 employee.

Let’s check this truly is a one-to-one relation. We’ve been given these rules: **One** employee could have only **one** valid identity card in our system. **One** identity card could belong to only **one** employee. We haven’t used the word “many”, so this can’t be any type of relation including the word “many”.

## Denormalization

Denormalization is a database optimization technique in which we add redundant data to one or more tables. This can help us avoid costly joins in a relational database.

**When and Why to Use Denormalization**

1. **Maintaining history**: Data can change during time, and we need to store values that were valid when a record was created. What kind of changes do we mean? Well, a person’s first and last name can change; a client also can change their business name or any other data. Task details should contain values that were actual at the moment a task was generated. We wouldn’t be able to recreate past data correctly if this didn’t happen. We could solve this problem by adding a table containing the history of these changes. In that case, a select query returning the task and a valid client name would become more complicated. Maybe an extra table isn’t the best solution.
2. **Improving query performance**: Some of the queries may use multiple tables to access data that we frequently need. Think of a situation where we’d need to join 10 tables to return the client’s name and the products that were sold to them. Some tables along the path could also contain large amounts of data. In that case, maybe it would be wise to add a client\_id attribute directly to the products\_sold table.
3. **Speeding up reporting**: We need certain statistics very frequently. Creating them from live data is quite time-consuming and can affect overall system performance. Let’s say that we want to track client sales over certain years for some or all clients. Generating such reports out of live data would “dig” almost throughout the whole database and slow it down a lot. And what happens if we use that statistic often?
4. **Computing commonly-needed values up front:** We want to have some values ready-computed so we don’t have to generate them in real time.

It’s important to point out that you don’t need to use denormalization if there are no performance issues in the application. But if you notice the system is slowing down – or if you’re aware that this could happen – then you should think about applying this technique. Before going with it, though, consider other options, like query optimization and proper indexing.

# SQL Server Essentials

## Components

* Database Engine
* Replication
* Full Text Search
* Analysis Services (SSAS)
* Reporting Services (SSRS)
* Integration Services (SSIS – ETL)
* Management Studio (SSMS)
* Configuration Manager (SSCM)
* Development Tools (SSD

# Transact SQL (T-SQL)

It is a query language, based on ANSI SQL Standard.

T-SQL has three general types of languages

1. **Data Definition Language - DDL**

CREATE, ALTER, DROP

1. **Data Manipulation Language – DML**

SELECT, INSERT, UPDATE, DELETE

1. **Data Control Language - DCL**

GRANT, REVOKE

## Data Types

### Main Categories

* Numeric
  + Exact numeric
  + Approximate numeric
* Temporal
* String
  + Unicode characters
  + Binary strings
* Other

### Exact numerics

* [bigint](https://docs.microsoft.com/en-us/sql/t-sql/data-types/int-bigint-smallint-and-tinyint-transact-sql?view=sql-server-ver15)
* [numeric](https://docs.microsoft.com/en-us/sql/t-sql/data-types/decimal-and-numeric-transact-sql?view=sql-server-ver15)
* [bit](https://docs.microsoft.com/en-us/sql/t-sql/data-types/bit-transact-sql?view=sql-server-ver15)
* [smallint](https://docs.microsoft.com/en-us/sql/t-sql/data-types/int-bigint-smallint-and-tinyint-transact-sql?view=sql-server-ver15)
* [decimal](https://docs.microsoft.com/en-us/sql/t-sql/data-types/decimal-and-numeric-transact-sql?view=sql-server-ver15)
* [smallmoney](https://docs.microsoft.com/en-us/sql/t-sql/data-types/money-and-smallmoney-transact-sql?view=sql-server-ver15)
* [int](https://docs.microsoft.com/en-us/sql/t-sql/data-types/int-bigint-smallint-and-tinyint-transact-sql?view=sql-server-ver15)
* [tinyint](https://docs.microsoft.com/en-us/sql/t-sql/data-types/int-bigint-smallint-and-tinyint-transact-sql?view=sql-server-ver15)
* [money](https://docs.microsoft.com/en-us/sql/t-sql/data-types/money-and-smallmoney-transact-sql?view=sql-server-ver15)

### Approximate numerics

* [float](https://docs.microsoft.com/en-us/sql/t-sql/data-types/float-and-real-transact-sql?view=sql-server-ver15)
* [real](https://docs.microsoft.com/en-us/sql/t-sql/data-types/float-and-real-transact-sql?view=sql-server-ver15)

### Date and time

* [date](https://docs.microsoft.com/en-us/sql/t-sql/data-types/date-transact-sql?view=sql-server-ver15)
* [datetimeoffset](https://docs.microsoft.com/en-us/sql/t-sql/data-types/datetimeoffset-transact-sql?view=sql-server-ver15)
* [datetime2](https://docs.microsoft.com/en-us/sql/t-sql/data-types/datetime2-transact-sql?view=sql-server-ver15)
* [smalldatetime](https://docs.microsoft.com/en-us/sql/t-sql/data-types/smalldatetime-transact-sql?view=sql-server-ver15)
* [datetime](https://docs.microsoft.com/en-us/sql/t-sql/data-types/datetime-transact-sql?view=sql-server-ver15)
* [time](https://docs.microsoft.com/en-us/sql/t-sql/data-types/time-transact-sql?view=sql-server-ver15)

### Character strings

* [char](https://docs.microsoft.com/en-us/sql/t-sql/data-types/char-and-varchar-transact-sql?view=sql-server-ver15)
* [varchar](https://docs.microsoft.com/en-us/sql/t-sql/data-types/char-and-varchar-transact-sql?view=sql-server-ver15)
* [text](https://docs.microsoft.com/en-us/sql/t-sql/data-types/ntext-text-and-image-transact-sql?view=sql-server-ver15)

### Binary strings

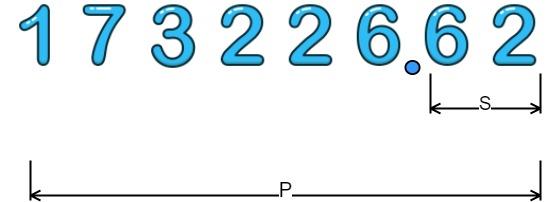
* [binary](https://docs.microsoft.com/en-us/sql/t-sql/data-types/binary-and-varbinary-transact-sql?view=sql-server-ver15)
* [varbinary](https://docs.microsoft.com/en-us/sql/t-sql/data-types/binary-and-varbinary-transact-sql?view=sql-server-ver15)
* [image](https://docs.microsoft.com/en-us/sql/t-sql/data-types/ntext-text-and-image-transact-sql?view=sql-server-ver15)

### Other data types

* [cursor](https://docs.microsoft.com/en-us/sql/t-sql/data-types/cursor-transact-sql?view=sql-server-ver15)
* [rowversion](https://docs.microsoft.com/en-us/sql/t-sql/data-types/rowversion-transact-sql?view=sql-server-ver15)
* [hierarchyid](https://docs.microsoft.com/en-us/sql/t-sql/data-types/hierarchyid-data-type-method-reference?view=sql-server-ver15)
* [uniqueidentifier](https://docs.microsoft.com/en-us/sql/t-sql/data-types/uniqueidentifier-transact-sql?view=sql-server-ver15)
* [sql\_variant](https://docs.microsoft.com/en-us/sql/t-sql/data-types/sql-variant-transact-sql?view=sql-server-ver15)
* [xml](https://docs.microsoft.com/en-us/sql/t-sql/xml/xml-transact-sql?view=sql-server-ver15)
* [Spatial Geometry Types](https://docs.microsoft.com/en-us/sql/t-sql/spatial-geometry/spatial-types-geometry-transact-sql?view=sql-server-ver15)
* [Spatial Geography Types](https://docs.microsoft.com/en-us/sql/t-sql/spatial-geography/spatial-types-geography?view=sql-server-ver15)
* [table](https://docs.microsoft.com/en-us/sql/t-sql/data-types/table-transact-sql?view=sql-server-ver15)

### decimal and numeric (Transact-SQL)

**decimal**[ **(**p[ **,**s] **)**] and **numeric**[ **(**p[ **,**s] **)**]



p (precision)  
The maximum total number of decimal digits to be stored. This number includes both the left and the right sides of the decimal point. The precision must be a value from 1 through the maximum precision of 38. The default precision is 18.

s (scale)  
The number of decimal digits that are stored to the right of the decimal point. This number is subtracted from p to determine the maximum number of digits to the left of the decimal point. Scale must be a value from 0 through p, and can only be specified if precision is specified. The default scale is 0 and so 0 <= s <= p.

There is a small difference between NUMERIC(p,s) and DECIMAL(p,s). NUMERIC determines the **exact precision and scale**. DECIMAL specifies **only the exact scale**; the precision is equal or greater than what is specified by the coder. DECIMAL columns can have a larger-than-specified precision if this is more convenient or efficient for the database system.

## **Manage data with Transact- SQL**

To write correct and robust T-SQL code, it’s important to first understand the roots of the language, as well as a concept called logical query processing. You also need to understand the structure of the SELECT statement and how to use its clauses to perform data manipulation tasks like filtering and sorting. You often need to combine data from different sources, and one of the ways to achieve this in T-SQL is using set operators.

### **Foundations of T-SQL**

T-SQL is based on strong mathematical foundations. Understanding some of the key principles from those foundations can help you better understand the language you are dealing with. Then you will think in T-SQL terms when coding in T-SQL, as opposed to coding with T-SQL while thinking in procedural terms.

SQL Server also supports other languages, like Microsoft Visual C# and Microsoft Visual Basic, but T-SQL is usually the preferred language for data management and manipulation.

Standard SQL is based on the relational model, which is a mathematical model for data management and manipulation. A relation in the relational model is what SQL represents with a table. A relation has a heading and a body. The heading is a set of attributes (what SQL attempts to represent with columns), each of a given type. An attribute is identified by name and type name. The body is a set of tuples (what SQL attempts to represent with rows). Each tuple’s heading is the heading of the relation. Each value of each tuple’s attribute is of its respective type.

Even when the table doesn’t allow duplicate rows, a query against the table can still return duplicate rows in its result. Consider the following query:

USE TSQLV4;

SELECT country

FROM HR.Employees;

T-SQL does give you enough tools so that if you want to follow relational theory, you can do so. For example, the language provides you with a DISTINCT clause to remove duplicates. Here’s the revised query:

SELECT DISTINCT country

FROM HR.Employees;

Another fundamental aspect of a set is that there’s no relevance to the order of the elements. For this reason, rows in a table have no particular order, conceptually.

SQL Server can choose between different physical access methods to process the query, knowing that it doesn’t need to guarantee the order in the result. For example, SQL Server could decide to parallelize the query or scan the data in file order (as opposed to index order).

If you do need to guarantee a specific presentation order to the rows in the result, you need to add an ORDER BY clause to the query, as follows:

SELECT empid, lastname

FROM HR.Employees

ORDER BY empid;

This time, the result isn’t relational, it’s what standard SQL calls a cursor. The order of the rows in the output is guaranteed based on the empid attribute.

T-SQL does keep track of ordinal positions of columns based on their order of appearance in the table definition. When you issue a query with SELECT \*, you are guaranteed to get the columns in the result based on definition order. Also, T-SQL allows referring to ordinal positions of columns from the result in the ORDER BY clause, as follows:

SELECT empid, lastname

FROM HR.Employees

ORDER BY 1;

However, this practice is not recommended.

T-SQL has another deviation from the relational model in that it allows defining result columns based on an expression without assigning a name to

the target column. For example, the following query is valid in T-SQL:

SELECT empid, firstname + ' ' + lastname

FROM HR.Employees;

But according to the relational model, all attributes must have names. In order for the query to be relational, you need to assign an alias to the target

attribute. You can do so by using the AS clause, as follows:

SELECT empid, firstname + ' ' + lastname AS fullname

FROM HR.Employees;

Also, with T-SQL a query can return multiple result columns with the same name. For example, consider a join between two tables, T1 and T2, both with a column called keycol. With T-SQL, a SELECT list can look like the following:

SELECT T1.keycol, T2.keycol ...

For the result to be relational, all attributes must have unique names, so you would need to use different aliases for the result attributes as follows:

SELECT T1.keycol AS key1, T2.keycol AS key2 ...

#### **Two value vs three value logic:**

As for predicates, following the law of excluded middle in mathematical

logic, a predicate can evaluate to true or false. In other words, predicates are

supposed to use two-valued logic. However, Codd wanted to reflect the

possibility for values to be missing in his model. He referred to two kinds of

missing values: missing but applicable (A-Values marker) and missing but

inapplicable (I-Values marker). As an example for a missing but applicable

case, consider a mobilephone attribute of an employee. Suppose that an

employee has a mobile phone, but did not want to provide this information,

for example, for privacy reasons. As an example for a missing but

inapplicable case, consider a salescommission attribute of an employee. This

attribute is applicable only to sales people, but not to other kinds of

employees. According to Codd, a language based on his model should

provide two different markers for the two cases. T-SQL—again, based on

standard SQL—implements only one general-purpose marker called NULL

for any kind of missing value. This leads to three-valued predicate logic.

Namely, when a predicate compares two values, for example, mobilephone =

‘(425) 555-0136’, if both are present, the result evaluates to either true or

false. But if at least one of them is NULL, the result evaluates to a third

logical value—unknown. That’s the case both when you use the equality

operator = and when you use an inequality operator such as: <>, >, >=, <, <=.

**Using correct terminology**

As an example of incorrect terms in T-SQL, people often use the terms

“field” and “record” to refer to what T-SQL calls “column” and “row,”

respectively. Fields and records are physical. Fields are what you have in user

interfaces in client applications, and records are what you have in files and

cursors. Tables are logical, and they have logical rows and columns.

Another example of an incorrect term is referring to “NULL values.” A

NULL is a marker for a missing value—not a value itself. Hence, the correct

usage of the term is either just “NULL” or “NULL marker.” Personally, I

prefer the former.

### **Understanding logical query processing**

T-SQL has both logical and physical sides to it. The logical side is the

conceptual interpretation of the query that explains what the correct result of

the query is. The physical side is the processing of the query by the database

engine. Physical processing must produce the result defined by logical query

processing. To achieve this goal, the database engine can apply optimization.

Optimization can rearrange steps from logical query processing or remove

steps altogether, but only as long as the result remains the one defined by

logical query processing. The focus of this section is logical query processing

—the conceptual interpretation of the query that guarantees returning what I

defined as the correct result.

T-SQL, being based on standard SQL, is a declarative English-like language.

In this language, declarative means you define what you want, as opposed to

imperative languages that define also how to achieve what you want.

You provide your instructions in an Englishlike manner. For example, consider the instruction, “Bring me a soda from the refrigerator.” Observe that in the English instruction, the object comes before the location. Consider the following request in T-SQL:

SELECT shipperid, phone, companyname

FROM Sales.Shippers;

Observe the similarity of the query’s keyed-in order to English. The query

first indicates the SELECT list with the attributes you want to return, and

then the FROM clause with the table you want to query.

Now try to think of the order in which the request needs to be logically

interpreted. For example, how would you define the instructions to a robot

instead of a human? The original English instruction to get a soda from the

refrigerator would probably need to be revised to something like, “Go to the

refrigerator; open the door; get a soda; bring it to me.”

Similarly, the logical processing of a query must first know which table is

being queried before it can know which attributes can be returned from that

table. Therefore, contrary to the keyed-in order of the previous query, the

logical query processing has to be as follows:

FROM Sales.Shippers

SELECT shipperid, phone, companyname

Following are the main query clauses specified in the order that you are

supposed to type them (known as “keyed-in order”):

**1.** SELECT

**2.** FROM

**3.** WHERE

**4.** GROUP BY

**5.** HAVING

**6.** ORDER BY

But as mentioned, the logical query processing order, which is the

conceptual interpretation order, is different. It starts with the FROM clause.

Here is the logical query processing order of the six main query clauses:

**1.** FROM

**2.** WHERE

**3.** GROUP BY

**4.** HAVING

**5.** SELECT

**6.** ORDER BY

Consider the following query as an example:

SELECT country, YEAR(hiredate) AS yearhired, COUNT(\*) AS

numemployees

FROM HR.Employees

WHERE hiredate >= '20140101'

GROUP BY country, YEAR(hiredate)

HAVING COUNT(\*) > 1

ORDER BY country, yearhired DESC;

This query is issued against the HR.Employees table. It filters only

employees that were hired in or after the year 2014. It groups the remaining

employees by country and the hire year. It keeps only groups with more than

one employee. For each qualifying group, the query returns the hire year and

count of employees, sorted by country and hire year, in descending order.

Note that an alias created by the SELECT phase isn’t even visible to other

expressions that appear in the same SELECT list. For example, the following

query isn’t valid:

SELECT empid, country, YEAR(hiredate) AS yearhired,

yearhired - 1 AS prevyear

FROM HR.Employees;

This query generates error:

The reason that this isn’t allowed is that all expressions that appear in the

same logical query-processing step are treated as a set, and a set has no order.

In other words, conceptually, T-SQL evaluates all expressions that appear in

the same phase in an all-at-once manner

#### **Getting started with the SELECT statement**

**The FROM clause**

According to logical query processing, the FROM clause is the first clause to

be evaluated logically in a SELECT query. The FROM clause has two main

roles:

* It’s the clause where you indicate the tables that you want to query.
* It’s the clause where you can apply table operators like joins to input

tables.

SELECT empid, firstname, lastname, country

FROM HR.Employees;

Observe the use of the two-part name to refer to the table. The first part

(HR) is the schema name and the second part (Employees) is the table name.

In some cases, T-SQL supports omitting the schema name, as in FROM

Employees, in which case it uses an implicit schema name resolution process.

It is considered a best practice to always explicitly indicate the schema name.

This practice can prevent you from ending up with a schema name that you

did not intend to use, and can also remove the cost involved in the implicit

resolution process, although this cost is minor.

In the FROM clause, you can alias the queried tables with your chosen

names. You can use the form <table> <alias>, as in HR.Employees E, or

<table> AS <alias>, as in HR.Employees AS E. The latter form is more

readable. When using aliases, the convention is to use short names, typically

one letter that is somehow indicative of the queried table, like E for

Employees. Then, when referring to an ambiguous column name in a multitable query (same column name appears in multiple queried tables), to avoid ambiguity, you add the table alias as a column prefix.

Note that if you assign an alias to a table, you basically rename the table

for the duration of the query. The original table name isn’t visible anymore;

only the alias is. Normally, you can prefix a column name you refer to in a

query with the table name, as in Employees.empid. However, if you aliased

the Employees table as E, the reference Employees.empid is invalid; you

have to use E.empid, as the following example demonstrates:

SELECT E.empid, firstname, lastname, country

FROM HR.Employees AS E;

If you try running this code by using the full table name as the column

prefix, the code will fail.

**The SELECT clause**

The SELECT clause of a query has two main roles:

* It evaluates expressions that define the attributes in the query’s result, assigning them with aliases if needed.
* Using a DISTINCT clause, you can eliminate duplicate rows in the

result if needed.

T-SQL supports using an asterisk (\*) as an alternative to listing all

attributes from the input tables, but this is considered a bad practice for a

number of reasons. Often, you need to return only a subset of the input

attributes, and using an \* is just a matter of laziness. By returning more

attributes than you really need, you can prevent SQL Server from using what

would normally be considered covering indexes with respect to the

interesting set of attributes. You also send more data than is needed over the

network, and this can have a negative impact on the system’s performance. In

addition, the underlying table definition could change over time; even if,

when the query was initially authored, \* really represented all attributes you

needed; it might not be the case anymore at a later point in time. For these

reasons and others, it is considered a best practice to always explicitly list the

attributes that you need.

In the SELECT clause, you can assign your own aliases to the expressions

that define the result attributes. There are a number of supported forms of

aliasing:

* <expression> AS <alias> as in empid AS employeeid,
* <expression> <alias> as in empid employeeid,
* <alias> = <expression> as in employeeid = empid.

There are two main uses for intentional attribute aliasing. One is renaming

—when you need the result attribute to be named differently than the source

attribute—for example, if you need to name the result attribute employeeid

instead of empid, as follows:

SELECT empid AS employeeid, firstname, lastname

FROM HR.Employees;

Another use is to assign a name to an attribute that results from an

expression that would otherwise be unnamed. For example, suppose you need

to generate a result attribute from an expression that concatenates the

firstname attribute, a space, and the lastname attribute. You use the following

query:

SELECT empid, firstname + N' ' + lastname

FROM HR.Employees;

By aliasing the expression, you assign a name to the result attribute,

making the result of the query relational, as follows.

SELECT empid, firstname + N' ' + lastname AS fullname

FROM HR.Employees;

There’s an interesting difference between standard SQL and T-SQL in

terms of minimal SELECT query requirements. According to standard SQL,

a SELECT query must have at minimum FROM and SELECT clauses.

Conversely, T-SQL supports a SELECT query with only a SELECT clause

and without a FROM clause. Such a query is as if issued against an imaginary

table that has only one row. For example, the following query is invalid

according to standard SQL, but is valid according to T-SQL:

SELECT 10 AS col1, 'ABC' AS col2;

The output of this query is a single row with attributes resulting from the

expressions with names assigned using the aliases:

col1 col2

----------- ----

10 ABC

#### Filtering data with predicates

Filtering data is one of the most fundamental aspects of T-SQL querying.

Almost every query that you write involves some form of filtering.

**Predicates and three-valued-logic**

Consider the following query, which filters only employees from the US:

SELECT empid, firstname, lastname, country, region, city

FROM HR.Employees

WHERE country = N'USA';

In case you’re wondering why the literal ‘USA’ is preceded with the letter

N as a prefix, that’s to denote a Unicode character string literal, because the

country column is of the data type NVARCHAR. Had the country column

been of a regular character string data type, such as VARCHAR, the literal

should have been just ‘USA’.

When NULLs are not possible in the data that you’re filtering, such as in

the above example, T-SQL uses two-valued logic; namely, for any given row

the predicate can evaluate to either true or false. The filter returns only the

rows for which the predicate evaluates to true and discards the ones for which

the predicate evaluates to false.

However, when NULLs are possible in the data, things get trickier. For

instance, consider the following query:

SELECT empid, firstname, lastname, country, region, city

FROM HR.Employees

WHERE region = N'WA';

Here you’re looking for only those employees who are from Washington

(have WA in the region attribute). It’s clear that the predicate evaluates to

true for rows that have WA in the region attribute and that those rows are

returned. It’s also clear that the predicate would have evaluated to false had

there been any rows with a present region other than WA, for example CA,

and that those rows would have been discarded. However, remember that the

predicate evaluates to unknown for rows that have a NULL in the region

attribute, and that the WHERE clause discards such rows. This happens to be

the desired behavior in our case because you know that when the region is

NULL, it can’t be Washington. However, remember that even when you use

the inequality operator <> a comparison with a NULL yields unknown. For

instance, suppose that you wanted to return only employees with a region

other than Washington, and that you used the following query in attempt to

achieve this:

SELECT empid, firstname, lastname, country, region, city

FROM HR.Employees

WHERE region <> N'WA';

The predicate evaluates to false for rows with WA in the region attribute

and those rows are discarded. The predicate would have evaluated to true had

there been rows with a present region other than WA, and those rows would

have been returned. However, the predicate evaluates to unknown for rows

with NULL in the region attribute, and those rows get discarded, even though

you know that if region is NULL, it cannot be Washington. This query

returns an empty set because our sample data contains only rows with either

WA or NULL in the region attribute:

This is an example where you need to intervene and add some logic to

your query to also return the rows where the region attribute is NULL. Be

careful though not to use an equality operator when looking for a NULL

because remember that nothing is considered equal to a NULL—not even

another NULL. The following query still returns an empty set:

SELECT empid, firstname, lastname, country, region, city

FROM HR.Employees

WHERE region <> N'WA'

OR region = NULL;

T-SQL supports the IS NULL and IS NOT NULL operators to check if a

NULL is or isn’t present, respectively. Here’s the solution query that

correctly handles NULLs:

SELECT empid, firstname, lastname, country, region, city

FROM HR.Employees

WHERE region <> N'WA'

OR region IS NULL;

**Combining predicates**

You can combine predicates in the WHERE clause by using the logical

operators AND and OR. You can also negate predicates by using the NOT

logical operator.

What can be surprising to some is what happens when you negate

unknown—NOT unknown is still unknown. Recall from the previous section

the query that returned all employees from Washington; the query used the

predicate region = N’WA’ in the WHERE clause. Suppose that you want to

return the employees that are not from WA, and for this you use the predicate

NOT region = N’WA’. It’s clear that cases that return false from the positive

predicate (say the region is NY) return true from the negated predicate. It’s

also clear that cases that return true from the positive predicate (say the

region is WA) return false from the negated predicate. However, when the

region is NULL, both the positive predicate and the negated one return

unknown and the row is discarded. So the right way for you to include NULL

cases in the result—if that’s what you know that you need to do—is to use

the IS NULL operator, as in NOT region = N’WA’ OR region IS NULL.

As for combining predicates, there are several interesting things to note.

Some precedence rules determine the logical evaluation order of the different

predicates. The NOT operator precedes AND and OR, and AND precedes

OR. For example, suppose that the WHERE filter in your query had the

following combination of predicates:

**Click here to view code image**

WHERE col1 = 'w' AND col2 = 'x' OR col3 = 'y' AND col4 =

'z'

Because AND precedes OR, you get the equivalent of the following:

**Click here to view code image**

WHERE (col1 = 'w' AND col2 = 'x') OR (col3 = 'y' AND col4

= 'z')

Trying to express the operators as pseudo functions, this combination of

operators is equivalent to OR( AND( col1 = ‘w’, col2 = ‘x’ ), AND( col3 =

‘y’, col4 = ‘z’ ) ).

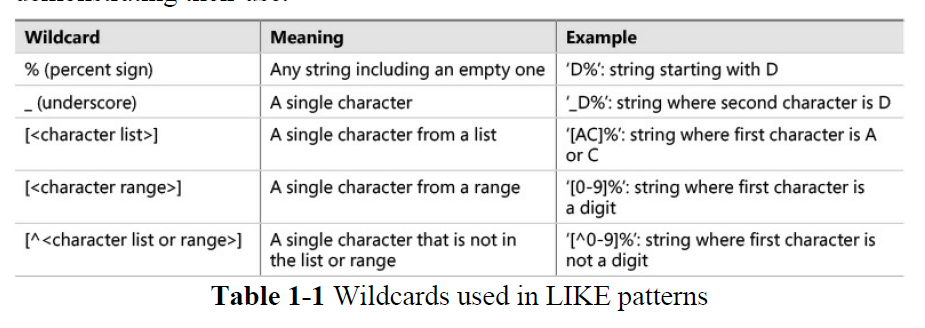
**Filtering character data**

T-SQL provides the LIKE predicate, which you can use to filter character

string data (regular and Unicode) based on pattern matching. The form of a

predicate using LIKE is as follows:

<column> LIKE <pattern>



As an example, suppose you want to return all employees whose last name

starts with the letter D. You would use the following query:

SELECT empid, firstname, lastname

FROM HR.Employees

WHERE lastname LIKE N'D%';

If you want to look for a character that is considered a wildcard, you can

indicate it after a character that you designate as an escape character by using

the ESCAPE keyword. For example, the expression col1 LIKE ‘!\_%’

ESCAPE ‘!’ looks for strings that start with an underscore (\_) by using an

exclamation point (!) as the escape character. Alternatively, you can place the

wildcard in square brackets, as in col1 LIKE ‘[\_]%’.

**Filtering date and time data**

You use the following query:

SELECT orderid, orderdate, empid, custid

FROM Sales.Orders

WHERE orderdate = '02/12/16';

If you’re an American, this form probably means February 12, 2016, to

you. However, if you’re British, this form probably means December 2,

2016. If you’re Japanese, it probably means December 16, 2002.

The question is, when SQL Server converts this character string to a date and time

type to align it with the filtered column’s type, how does it interpret the

value? As it turns out, it depends on the language of the login that runs the

code. Each login has a default language associated with it, and the default

language sets various session options on the login’s behalf, including one

called DATEFORMAT. A login with us\_english will have the

DATEFORMAT setting set to mdy, British to dmy, and Japanese to ymd.

The problem is, how do you as a developer express a date if you want it to be

interpreted the way you intended, regardless of who runs your code?

There are two main approaches. One is to use a form that is considered

language-neutral. For example, the form ‘20160212’ is always interpreted as

ymd, regardless of your language. Note that the form ‘2016-02-12’ is

considered language-neutral only for the data types DATE, DATETIME2,

and DATETIMEOFFSET. Unfortunately, due to historic reasons, this form is

considered language-dependent for the types DATETIME and

SMALLDATETIME. The advantage of the form without the separators is

that it is language-neutral for all date and time types. So the recommendation

is to write the query as follows:

SELECT orderid, orderdate, empid, custid

FROM Sales.Orders

WHERE orderdate = '20160212';

Another approach is to explicitly convert the string to the target type using

the CONVERT function, and indicating the style number that represents the

style that you used. You can find the documentation of the CONVERT

function with the different style numbers that it supports at

*https://msdn.microsoft.com/en-GB/library/ms187928.aspx*. For instance, to

use the U.S. style, specify style number 101, as CONVERT(DATE,

‘02/12/2016’, 101).

When filtering data stored in a DATETIME data type, you need to be very

careful with ranges. The recommended way to express a date and time range is with a closed-open interval as follows:

SELECT orderid, orderdate, empid, custid

FROM Sales.Orders2

WHERE orderdate >= '20160401' AND orderdate < '20160501';

This time the output contains only the orders placed in April 2016.

**Sorting data**

A query that doesn’t have an

explicit instruction to return the rows in a particular order doesn’t guarantee

the order of rows in the result. When you do need such a guarantee, the only

way to provide it is by adding an ORDER BY clause to the query.

For example, if you want to return information about employees from

Washington in the US, sorted by city, you specify the city column in the

ORDER BY clause as follows:

SELECT empid, firstname, lastname, city, MONTH(birthdate)

AS birthmonth

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY city;

If you don’t indicate a direction for sorting, ascending order is assumed by

default. You can be explicit and specify city ASC, but it means the same

thing as not indicating the direction. For descending ordering, you need to

explicitly specify DESC, as follows:

SELECT empid, firstname, lastname, city, MONTH(birthdate)

AS birthmonth

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY city DESC;

The city column isn’t unique within the filtered country and region, and

therefore, the ordering of rows with the same city (see Seattle, for example)

isn’t guaranteed. Fortunately,

you can specify multiple expressions in the ORDER BY list, separated by

commas. One use case of this capability is to apply a tiebreaker for ordering.

For example, you could define empid as the secondary sort column, as

follows:

SELECT empid, firstname, lastname, city, MONTH(birthdate)

AS birthmonth

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY city, empid;

You can indicate the

ordering direction on an expression-by-expression basis, as in ORDER BY

col1 DESC, col2, col3 DESC (col1 descending, then col2 ascending, then

col3 descending).

With T-SQL, you can sort by ordinal positions of columns in the SELECT

list, but it is considered a bad practice. Consider the following query as an

example:

SELECT empid, firstname, lastname, city, MONTH(birthdate)

AS birthmonth

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY 4, 1;

Note that you can order the result rows by elements that you’re not

returning. For example, the following query returns, for each qualifying

employee, the employee ID and city, ordering the result rows by the

employee birth date:

SELECT empid, city

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY birthdate;

Here’s the output of this query:

empid city

----------- ---------------

4 Redmond

1 Seattle

2 Tacoma

8 Seattle

3 Kirkland

Of course, the result would appear much more meaningful if you included

the birthdate attribute, but if it makes sense for you not to, it’s perfectly valid.

The rule is that you can order the result rows by elements that are not part of

the SELECT list, as long as those elements would have normally been

allowed there. This rule changes when the DISTINCT clause is also

specified, and for a good reason. When DISTINCT is used, duplicates are

removed; then the result rows don’t necessarily map to source rows in a one-to-one manner, rather than one-to-many. For example, try to reason why the

following query isn’t valid:

SELECT DISTINCT city

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY birthdate;

You can have multiple employees—each with a different birth date—from

the same city. But you’re returning only one row for each distinct city in the

result. So given one city (say, Seattle) with multiple employees, which of the

employee birth dates should apply as the ordering value? The query won’t

just pick one; rather, it simply fails.

So, in case the DISTINCT clause is used, you are limited in the ORDER

BY list to only elements that appear in the SELECT list, as in the following

query:

SELECT DISTINCT city

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY city;

What’s also interesting to note about the ORDER BY clause is that it gets

evaluated conceptually after the SELECT clause—unlike most other query

clauses. This means that column aliases assigned in the SELECT clause are

actually visible to the ORDER BY clause. As an example, the following

query uses the MONTH function to return the birth month, assigning the

expression with the column alias birthmonth. The query then refers to the

column alias birthmonth directly in the ORDER BY clause:

SELECT empid, firstname, lastname, city, MONTH(birthdate)

AS birthmonth

FROM HR.Employees

WHERE country = N'USA' AND region = N'WA'

ORDER BY birthmonth;

Another tricky aspect of ordering is treatment of NULLs. Recall that a

NULL represents a missing value, so when comparing a NULL to anything,

you get the logical result unknown. That’s the case even when comparing two

NULLs. So it’s not that trivial to ask how NULLs should behave in terms of

sorting. Should they all sort together? If so, should they sort before or after

non-NULL values? Standard SQL says that NULLs should sort together, but

leaves it to the implementation to decide whether to sort them before or after

non-NULL values. In SQL Server the decision was to sort them before non-

NULLs (when using an ascending direction). As an example, the following

query returns for each order the order ID and shipped date, ordered by the

latter:

SELECT orderid, shippeddate

FROM Sales.Orders

WHERE custid = 20

ORDER BY shippeddate;

Remember that unshipped orders have a NULL in the shippeddate column;

hence, they sort before shipped orders, as the query output shows:

orderid shippeddate

----------- -----------

11008 NULL

11072 NULL

10258 2014-07-23

10263 2014-07-31

#### **Filtering data with TOP and OFFSET-FETCH**

Besides supporting filters that are based on predicates, like the WHERE

filter, T-SQL also supports filters that are based on a number, or percent of

rows and ordering. Those are the TOP and OFFSET-FETCH filters. The

former is used in a lot of common filtering tasks, and the latter is typically

used in more specialized paging-related tasks.

**Filtering data with TOP**

With the TOP option, you can filter a requested number or percent of rows

from the query result based on indicated ordering. You specify the TOP

option in the SELECT clause followed by the requested number of rows in

parentheses (as a BIGINT typed value). The ordering specification of the

TOP filter is based on the same ORDER BY clause that is normally used for

presentation ordering.

As an example, the following query returns the three most recent orders:

SELECT TOP (3) orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

You can also specify a percent of rows to filter instead of a number. To do

so, specify a FLOAT value in the range 0 through 100 in the parentheses, and

the keyword PERCENT after the parentheses, as follows:

SELECT TOP (1) PERCENT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

The PERCENT option computes the ceiling of the resulting number of

rows if it’s not whole. In this example, without the TOP option, the number

of rows in the result is 830. Filtering 1 percent gives you 8.3, and then the

ceiling of this value gives you 9; hence, the query returns 9 rows:

The TOP option isn’t limited to a constant input; instead, it allows you to

specify a self-contained expression. From a practical perspective, this

capability is especially important when you need to pass a parameter or a

variable as input, as the following code demonstrates:

DECLARE @n AS BIGINT = 5;

SELECT TOP (@n) orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

In most cases, you need your TOP option to rely on some ordering

specification, but as it turns out, an ORDER BY clause isn’t mandatory. For

example, the following query is technically valid:

SELECT TOP (3) orderid, orderdate, custid, empid

FROM Sales.Orders;

However, the query isn’t deterministic. The query filters three rows, but

you have no guarantee which three rows will be returned.

If you are really after three arbitrary rows, it might be a good

idea to add an ORDER BY clause with the expression (SELECT NULL) to

let people know that your choice is intentional and not an oversight. Here’s

how your query would look:

SELECT TOP (3) orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY (SELECT NULL);

Note that even when you do have an ORDER BY clause, in order for the

query to be completely deterministic, the ordering must be unique. For

example, consider again the first query from this section:

SELECT TOP (3) orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

The orderdate column isn’t unique, so the ordering in case of ties is

arbitrary.

consider again the first query from this section:

SELECT TOP (3) orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

what if there are other rows in the result without TOP that have the

same order date as in the last row here? You don’t always care about

guaranteeing deterministic or repeatable results; but if you do, two options

are available to you. One option is to ask to include all ties with the last row

by adding the WITH TIES option, as follows:

SELECT TOP (3) WITH TIES orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC;

Of course, this could result in returning more rows than you asked for.

**Filtering data with OFFSET-FETCH**

The OFFSET-FETCH option is a filtering option that, like TOP, you can use

to filter data based on a specified number of rows and ordering. But unlike

TOP, it is standard, and also has a skipping capability, making it useful for

ad-hoc paging purposes.

The OFFSET and FETCH clauses appear right after the ORDER BY

clause, and in fact, in T-SQL, they require an ORDER BY clause to be

present. You first specify the OFFSET clause indicating how many rows you

want to skip (0 if you don’t want to skip any); you then optionally specify the

FETCH clause indicating how many rows you want to filter. For example,

the following query defines ordering based on order date descending,

followed by order ID descending; it then skips the first 50 rows and fetches

the next 25 rows:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC, orderid DESC

OFFSET 50 ROWS FETCH NEXT 25 ROWS ONLY;

In T-SQL—contrary to standard SQL—a

FETCH clause requires an OFFSET clause to be present. So if you do want to

filter some rows but skip none, you still need to specify the OFFSET clause

with 0 ROWS.

In order to make the syntax intuitive, you can use the keywords NEXT or

FIRST interchangeably. When skipping some rows, it might be more

intuitive to you to use the keywords FETCH NEXT to indicate how many

rows to filter; but when not skipping any rows, it might be more intuitive to

you to use the keywords FETCH FIRST, as follows:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC, orderid DESC

OFFSET 0 ROWS FETCH FIRST 25 ROWS ONLY;

For similar reasons, you can use the singular form ROW or the plural form

ROWS interchangeably, both for the number of rows to skip and for the

number of rows to filter. But it’s not like you will get an error if you say

FETCH NEXT 1 ROWS or FETCH NEXT 25 ROW.

In T-SQL, a FETCH clause requires an OFFSET clause, but the OFFSET

clause doesn’t require a FETCH clause. In other words, by indicating an

OFFSET clause, you’re requesting to skip some rows; then by not indicating

a FETCH clause, you’re requesting to return all remaining rows. For

example, the following query requests to skip 50 rows, returning all the rest.

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC, orderid DESC

OFFSET 50 ROWS;

the OFFSET-FETCH option requires an ORDER

BY clause. But what if you need to filter a certain number of rows based on

arbitrary order? To do so, you can specify the expression (SELECT NULL)

in the ORDER BY clause, as follows:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY (SELECT NULL)

OFFSET 0 ROWS FETCH FIRST 3 ROWS ONLY;

With both the OFFSET and the FETCH clauses, you can use expressions

as inputs. This is very handy when you need to compute the input values

dynamically. For example, suppose that you’re implementing a paging

solution where you return to the user one page of rows at a time. The user

passes as input parameters to your procedure or function the page number

they are after (@pagenum parameter) and page size (@pagesize parameter).

This means that you need to skip as many rows as @pagenum minus one

times @pagesize, and fetch the next @pagesize rows. This can be

implemented using the following code (using local variables for simplicity):

DECLARE @pagesize AS BIGINT = 25, @pagenum AS BIGINT = 3;

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate DESC, orderid DESC

OFFSET (@pagenum - 1) \* @pagesize ROWS FETCH NEXT

@pagesize ROWS ONLY;

## Combining sets with set operators

Set operators operate on two result sets of queries, comparing complete rows

between the results. Depending on the result of the comparison and the

operator used, the operator determines whether to return the row or not. TSQL supports the following operators:

* UNION,
* UNION ALL,
* INTERSECT,
* EXCEPT.

The general form of code using these operators is as follows:

<query 1>

<operator>

<query 2>

[ORDER BY <order\_by\_list>];

**Guidelines:**

Because complete rows are matched between the result sets, the

number of columns in the queries has to be the same and the column

types of corresponding columns need to be compatible (implicitly

convertible).

These operators use distinctness-based comparison and not equality

based. Consequently, a comparison between two NULLs yields true,

and a comparison between a NULL and a non-NULL value yields a

false. This is in contrast to filtering clauses like WHERE, ON, and

HAVING, which yield unknown when comparing a NULL with

anything using both equality and inequality operators.

Because these operators are set operators and not cursor operators, the

individual queries are not allowed to have ORDER BY clauses.

You can optionally add an ORDER BY clause that determines

presentation ordering of the result of the set operator.

The column names of result columns are determined by the first query.

### UNION and UNION ALL

The UNION operator unifies the results of the two input queries. As a set

operator, UNION has an implied DISTINCT property, meaning that it does

not return duplicate rows. Figure 1-2 shows an illustration of the UNION

operator.

As an example for using the UNION operator, the following query returns

locations that are employee locations, or customer locations, or both:

SELECT country, region, city

FROM HR.Employees

UNION

SELECT country, region, city

FROM Sales.Customers;

If you want to keep the duplicates—for example, to later group the rows

and count occurrences—you need to use the UNION ALL operator instead of

UNION. The UNION ALL operator unifies the results of the two input

queries, but doesn’t try to eliminate duplicates.

As an example, the following query unifies employee locations and

customer locations using the UNION ALL operator:

SELECT country, region, city

FROM HR.Employees

UNION ALL

SELECT country, region, city

FROM Sales.Customers;

It’s important to use UNION ALL in such a case from a performance standpoint because with UNION, SQL Server can try to eliminate duplicates, incurring unnecessary cost.

### INTERSECT

The INTERSECT operator returns only distinct rows that are common to

both sets. In other words, if a row appears at least once in the first set and at

least once in the second set, it appears once in the result of the INTERSECT

operator.

As an example, the following code uses the INTERSECT operator to

return distinct locations that are both employee and customer locations

(locations where there’s at least one employee and at least one customer):

SELECT country, region, city

FROM HR.Employees

INTERSECT

SELECT country, region, city

FROM Sales.Customers;

### EXCEPT

The EXCEPT operator performs set difference. It returns distinct rows that

appear in the result of the first query but not the second. In other words, if a

row appears at least once in the first query result and zero times in the

second, it’s returned once in the output.

As an example for using EXCEPT, the following query returns locations

that are employee locations but not customer locations:

SELECT country, region, city

FROM HR.Employees

EXCEPT

SELECT country, region, city

FROM Sales.Customers;

With UNION and INTERSECT, the order of the input queries doesn’t

matter. However, with EXCEPT, there’s different meaning to:

<query 1> EXCEPT <query 2>

Versus:

<query 2> EXCEPT <query 1>

Finally, set operators have precedence: INTERSECT precedes UNION and

EXCEPT, and UNION and EXCEPT are evaluated from left to right based on

their position in the expression. Consider the following set operators:

<query 1> UNION <query 2> INTERSECT <query 3>;

First, the intersection between query 2 and query 3 takes place, and then a

union between the result of the intersection and query 1. You can always

force precedence by using parentheses. So, if you want the union to take

place first, you use the following form:

(<query 1> UNION <query 2>) INTERSECT <query 3>;

## Query multiple tables by using joins

Often, data that you need to query is spread across multiple tables. The tables

are usually related through keys, such as a foreign key in one side and a

primary key in the other. Then you can use joins to query the data from the

different tables and match the rows that need to be related.

### Cross joins

A cross join is the simplest type of join, though not the most commonly used

one. This join performs what’s known as a Cartesian product of the two input

tables. In other words, it performs a multiplication between the tables,

yielding a row for each combination of rows from both sides. If you have m

rows in table T1 and n rows in table T2, the result of a cross join between T1

and T2 is a virtual table with m × n rows.

Consider an example from the TSQLV4 sample database. This database

contains a table called dbo.Nums that has a column called n with a sequence

of integers from 1 and on. Your task is to use the Nums table to generate a

result with a row for each weekday (1 through 7) and shift number (1 through

3), assuming there are three shifts a day. The result can later be used as the

basis for building information about activities in the different shifts in the

different days. With seven days in the week, and three shifts every day, the

result should have 21 rows.

Here’s a query that achieves the task by performing a cross join between

two instances of the Nums table—one representing the days (aliased as D),

and the other representing the shifts (aliased as S):

USE TSQLV4;

SELECT D.n AS theday, S.n AS shiftno

FROM dbo.Nums AS D

CROSS JOIN dbo.Nums AS S

WHERE D.n <= 7

AND S.N <= 3

ORDER BY theday, shiftno;

Here’s the output of this query:

theday shiftno

----------- -----------

1 1

1 2

1 3

2 1

2 2

2 3

3 1

3 2

3 3

4 1

...

The Nums table has 100,000 rows. According to logical query processing,

the first step in the processing of the query is evaluating the FROM clause.

The cross join operates in the FROM clause, performing a Cartesian product

between the two instances of Nums, yielding a table with 10,000,000,000

rows (not to worry, that’s only conceptually). Then the WHERE clause filters

only the rows where the column D.n is less than or equal to 7, and the column

S.n is less than or equal to 3. After applying the filter, the result has 21

qualifying rows. The SELECT clause then returns D.n aliasing it theday, and

S.n aliasing it shiftno.

Fortunately, SQL Server doesn’t have to follow logical query processing

literally as long as it can return the correct result. That’s what optimization is

all about—returning the result as fast as possible. SQL Server knows that

with a cross join followed by a filter it can evaluate the filters first (which is

especially efficient when there are indexes to support the filters), and then

match the remaining rows. This optimization technique is called *predicate*

*pushdown*.

Both standard SQL and T-SQL support an older

syntax where you specify a comma between the table names, as in FROM T1,

T2. However, for a number of reasons, it is recommended to stick to the

newer syntax; it is less prone to errors and allows for more consistent code.

### Inner joins

With an inner join, you can match rows from two tables based on a predicate

—usually one that compares a primary key value in one side to a foreign key

value in another side.

As an example, the following query returns suppliers from Japan and the

products they supply:

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice

FROM Production.Suppliers AS S

INNER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

WHERE S.country = N'Japan';

A very common question is, “What’s the difference between the ON and

the WHERE clauses, and does it matter if you specify your predicate in one

or the other?” The answer is that for inner joins it doesn’t matter. Both

clauses serve the same filtering purpose. Both filter only rows for which the

predicate evaluates to true and discard rows for which the predicate evaluates

to false or unknown. In terms of logical query processing, the WHERE is

evaluated right after the FROM, so conceptually it is equivalent to

concatenating the predicates with an AND operator, forming a conjunction of

predicates. SQL Server knows this, and therefore can internally rearrange the

order in which it evaluates the predicates in practice, and it does so based on

cost estimates.

For these reasons, if you wanted, you could rearrange the placement of the

predicates from the previous query, specifying both in the ON clause, and

still retain the original meaning, as follows:

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice

FROM Production.Suppliers AS S

INNER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

AND S.country = N'Japan';

For many people, though, it’s intuitive to specify the predicate that

matches columns from both sides in the ON clause, and predicates that filter

columns from only one side in the WHERE clause.

As another example for an inner join, the following query joins two

instances of the HR.Employees table to match employees with their managers

(a manager is also an employee, hence the self-join):

SELECT E.empid,

E.firstname + N' ' + E.lastname AS emp,

M.firstname + N' ' + M.lastname AS mgr

FROM HR.Employees AS E

INNER JOIN HR.Employees AS M

ON E.mgrid = M.empid;

This query generates the following output:

empid emp mgr

----------- ------------------------------- --------------

-----------------

2 Don Funk Sara Davis

3 Judy Lew Don Funk

4 Yael Peled Judy Lew

5 Sven Mortensen Don Funk

6 Paul Suurs Sven Mortensen

Note that only eight rows were returned even though there are nine rows in

the table. The reason is that the CEO (Sara Davis, employee ID 1) has no

manager, and therefore, her mgrid column is NULL. Remember that an inner

join does not return rows that don’t find matches.

As with cross joins, both standard SQL and T-SQL support an older syntax

for inner joins where you specify a comma between the table names, and then

all predicates in the WHERE clause. But as mentioned, it is considered best

practice to stick to the newer syntax with the JOIN keyword. When using the

older syntax, if you forget to indicate the join predicate, you end up with an

unintentional cross join. When using the newer syntax, an inner join isn’t

valid syntactically without an ON clause, so if you forget to indicate the join

predicate, the parser will generate an error.

Because an inner join is the most commonly used type of join, the standard

decided to make it the default in case you specify just the JOIN keyword. So

T1 JOIN T2 is equivalent to T1 INNER JOIN T2.

### Outer joins

With outer joins, you can request to preserve all rows from one or both sides

of the join, never mind if there are matching rows in the other side based on

the ON predicate.

By using the keywords LEFT OUTER JOIN (or LEFT JOIN for short),

you ask to preserve the left table. The join returns what an inner join

normally would—that is, matches (call those inner rows). In addition, the join

also returns rows from the left table that have no matches in the right table

(call those outer rows), with NULLs used as placeholders in the right side.

As an example, the following query returns suppliers from Japan and the

products they supply, including suppliers from Japan that don’t have related

products.

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice

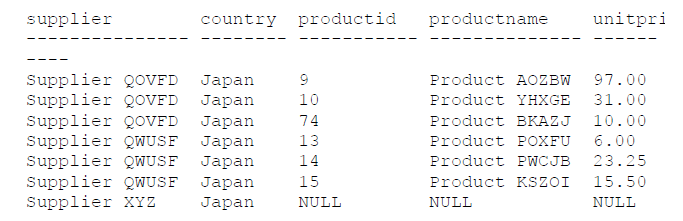
FROM Production.Suppliers AS S

LEFT OUTER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

WHERE S.country = N'Japan';

This query generates the following output:



Because the Production.Suppliers table is the preserved side of the join,

Supplier XYZ is returned even though it has no matching products. As you

recall, an inner join did not return this supplier.

It is very important to understand that, with outer joins, the ON and

WHERE clauses play very different roles, and therefore, they aren’t

interchangeable. The WHERE clause still plays a simple filtering role—

namely, it keeps true cases and discards false and unknown cases. In our

query, the WHERE clause filters only suppliers from Japan, so suppliers that

aren’t from Japan simply don’t show up in the output.

However, the ON clause doesn’t play a simple filtering role; rather, it’s a

more sophisticated matching role. In other words, a row in the preserved side

will be returned whether the ON predicate finds a match for it or not. So the

ON predicate only determines which rows from the nonpreserved side get

matched to rows from the preserved side—not whether to return the rows

from the preserved side. In our query, the ON clause matches rows from both

sides by comparing their supplier ID values. Because it’s a matching

predicate (as opposed to a filter), the join won’t discard suppliers; instead, it

only determines which products get matched to each supplier. But even if a

supplier has no matches based on the ON predicate, the supplier is still

returned. In other words, ON is not final with respect to the preserved side of

the join. WHERE is final. So when in doubt, whether to specify the predicate

in the ON or WHERE clauses, ask yourself: Is the predicate used to filter or

match? Is it supposed to be final or nonfinal?

With this in mind, guess what happens if you specify both the predicate

that compares the supplier IDs from both sides, and the one comparing the

supplier country to Japan in the ON clause? Try it.

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice

FROM Production.Suppliers AS S

LEFT OUTER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

AND S.country = N'Japan';

Now that both predicates appear in the ON clause, both serve a matching

purpose. What this means is that all suppliers are returned—even those that

aren’t from Japan.

Just like you can use a left outer join to preserve the left side, you can use a

right outer join to preserve the right side. Use the keywords RIGHT OUTER

JOIN (or RIGHT JOIN in short).

T-SQL also supports a full outer join (FULL OUTER JOIN, or FULL

JOIN in short) that preserves both sides.

A full outer join returns the matched rows, which are normally returned

from an inner join; plus rows from the left that don’t have matches in the

right, with NULLs used as placeholders in the right side; plus rows from the

right that don’t have matches in the left, with NULLs used as placeholders in

the left side. It’s not common to need a full outer join because most

relationships between tables allow only one of the sides to have rows that

don’t have matches in the other, in which case, a one-sided outer join is

needed.

### Queries with composite joins and NULLs in join Columns

Some joins can be a bit tricky to handle, for instance when the join columns

can have NULLs, or when you have multiple join columns—what’s known

as a composite join.

Earlier in the inner joins section is a query that matched employees and

their managers. Remember that the inner join eliminated the CEO’s row

because the mgrid is NULL in that row, and therefore the join found no

matching manager. If you want to include the CEO’s row, you need to use an

outer join to preserve the side representing the employees (E) as follows:

SELECT E.empid,

E.firstname + N' ' + E.lastname AS emp,

M.firstname + N' ' + M.lastname AS mgr

FROM HR.Employees AS E

LEFT OUTER JOIN HR.Employees AS M

ON E.mgrid = M.empid;

When you need to join tables that are related based on multiple columns,

the join is called a *composite join* and the ON clause typically consists of a

conjunction of predicates (predicates separated by AND operators) that match

the corresponding columns from the two sides. Sometimes you need more

complex predicates, especially when NULLs are involved. I’ll demonstrate

this by using a pair of tables. One table is called EmpLocations and it holds

employee locations and the number of employees in each location. Another

table is called CustLocations and it holds customer locations and the number

of customers in each location. Run the following code to create these tables

and populate them with sample data:

DROP TABLE IF EXISTS dbo.EmpLocations;

SELECT country, region, city, COUNT(\*) AS numemps

INTO dbo.EmpLocations

FROM HR.Employees

GROUP BY country, region, city;

ALTER TABLE dbo.EmpLocations ADD CONSTRAINT

UNQ\_EmpLocations

UNIQUE CLUSTERED(country, region, city);

DROP TABLE IF EXISTS dbo.CustLocations;

SELECT country, region, city, COUNT(\*) AS numcusts

INTO dbo.CustLocations

FROM Sales.Customers

GROUP BY country, region, city;

ALTER TABLE dbo.CustLocations ADD CONSTRAINT

UNQ\_CustLocations

UNIQUE CLUSTERED(country, region, city);

There’s a key defined in both tables on the location attributes: country,

region, and city. Instead of using a primary key constraint I used a unique

constraint to enforce the key because the region attribute allows NULLs, and

between the two types of constraints, only the latter allows NULLs. I also

specified the CLUSTERED keyword in the unique constraint definitions to

have SQL Server create a clustered index type to enforce the constraint’s

uniqueness property. This index will be beneficial in supporting joins

between the tables based on the location attributes as well filters based on

those attributes.

Query the EmpLocations table to see its contents:

SELECT country, region, city, numemps

FROM dbo.EmpLocations;

Suppose that you needed to join the two tables returning only matched

locations, with both the employee and customer counts returned along with

the location attributes. Your first attempt might be to write a composite join

with an ON clause that has a conjunction of simple equality predicates as

follows:

SELECT EL.country, EL.region, EL.city, EL.numemps,

CL.numcusts

FROM dbo.EmpLocations AS EL

INNER JOIN dbo.CustLocations AS CL

ON EL.country = CL.country

AND EL.region = CL.region

AND EL.city = CL.city;

The problem is that the region column supports NULLs representing cases

where the region is irrelevant (missing but inapplicable) and when you

compare NULLs with an equality-based predicate the result is the logical

value unknown, in which case the row is discarded. For instance, the location

UK, NULL, London appears in both tables, and therefore you expect to see it

in the result of the join, but you don’t. A common way for people to resolve

this problem is to use the ISNULL or COALESCE functions to substitute a

NULL in both sides with a value that can’t normally appear in the data, and

this way when both sides are NULL you get a true back from the comparison.

Here’s an example for implementing this solution using the ISNULL

function:

SELECT EL.country, EL.region, EL.city, EL.numemps,

CL.numcusts

FROM dbo.EmpLocations AS EL

INNER JOIN dbo.CustLocations AS CL

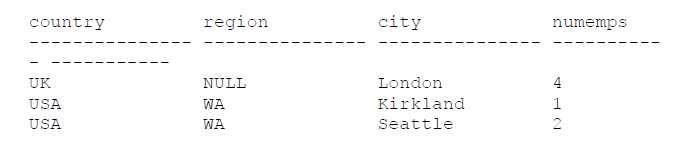
ON EL.country = CL.country

AND ISNULL(EL.region, N'<N/A>') = ISNULL(CL.region,

N'<N/A>')

AND EL.city = CL.city;

This time the query generates the correct result:



You can handle NULLs in a manner that gives you the desired logical

meaning and that at the same time is considered order preserving by the

optimizer using the predicate: (EL.region = CL.region OR (EL.region IS

NULL AND CL.region IS NULL)). Here’s the complete solution query:

SELECT EL.country, EL.region, EL.city, EL.numemps,

CL.numcusts

FROM dbo.EmpLocations AS EL

INNER JOIN dbo.CustLocations AS CL

ON EL.country = CL.country

AND (EL.region = CL.region OR (EL.region IS NULL AND

CL.region IS NULL))

AND EL.city = CL.city;

Recall that when set operators combine query results they compare

corresponding attributes using distinctness and not equality, producing true

when comparing two NULLs. However, one drawback that set operators

have is that they compare complete rows. Unlike joins, which allow

comparing a subset of the attributes and return additional ones in the result,

set operators must compare all attributes from the two input queries. But in

T-SQL, you can combine joins and set operators to benefit from the

advantages of both tools. Namely, rely on the distinctness-based comparison

of set operators and the ability of joins to return additional attributes beyond

what you compare. In our querying task, the solution looks like this:

SELECT EL.country, EL.region, EL.city, EL.numemps,

CL.numcusts

FROM dbo.EmpLocations AS EL

INNER JOIN dbo.CustLocations AS CL

ON EXISTS (SELECT EL.country, EL.region, EL.city

INTERSECT

SELECT CL.country, CL.region, CL.city);

### Multi-join queries

It’s important to remember that a join in T-SQL takes place conceptually

between two tables at a time. A multi-join query evaluates the joins

conceptually from left to right. So the result of one join is used as the left

input to the next join.

As an example, suppose that you wanted to return all suppliers from Japan,

and matching products where relevant. For this, you need an outer join

between Production.Suppliers and Production.Products, preserving Suppliers.

But you also want to include product category information, so you add an

inner join to Production.Categories, as follows:

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice,

C.categoryname

FROM Production.Suppliers AS S

LEFT OUTER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

INNER JOIN Production.Categories AS C

ON C.categoryid = P.categoryid

WHERE S.country = N'Japan';

Conceptually, the first join included outer rows (suppliers with no

products) but produced NULLs as placeholders in the product attributes in

those rows. Then the join to Production.Categories compared the NULLs in

the categoryid column in the outer rows to categoryid values in

Production.Categories, and discarded those rows. In short, the inner join that

followed the outer join nullified the outer part of the join. In fact, if you look

at the query plan for this query, you will find that the optimizer didn’t even

bother to process the join between Production.Suppliers and

Production.Products as an outer join. It detected the contradiction between

the outer join and the subsequent inner join, and converted the first join to an

inner join too.

There are a number of ways to address this problem. One is to use a LEFT

OUTER in both joins, like so:

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice,

C.categoryname

FROM Production.Suppliers AS S

LEFT OUTER JOIN Production.Products AS P

ON S.supplierid = P.supplierid

LEFT OUTER JOIN Production.Categories AS C

ON C.categoryid = P.categoryid

WHERE S.country = N'Japan';

Another option is to use an interesting capability in the language—separate

some of the joins to their own independent logical phase. What you’re after is

a left outer join between Production.Suppliers and the result of the inner join

between Production.Products and Production.Categories. You can phrase

your query exactly like this:

SELECT

S.companyname AS supplier, S.country,

P.productid, P.productname, P.unitprice,

C.categoryname

FROM Production.Suppliers AS S

LEFT OUTER JOIN

(Production.Products AS P

INNER JOIN Production.Categories AS C

ON C.categoryid = P.categoryid)

ON S.supplierid = P.supplierid

WHERE S.country = N'Japan';

## Implement functions and aggregate data

T-SQL supports many built-in functions that you can use to manipulate data.

Scalar-valued functions return a single value and table-valued functions

return a table result. Use of built-in functions can improve developer

productivity, but you also need to understand cases where their use in certain

context can end up negatively affecting query performance. It’s also

important to understand the concept of function determinism and its effects

on your queries.

### Type conversion functions

T-SQL supports a number of functions that can convert a source expression

to a target data type. In my examples I use constants as the source values to

demonstrate the use of the functions, but typically you apply such functions

to columns or expressions based on columns as part of a query.

The two fundamental functions that T-SQL supports for conversion

purposes are CAST and CONVERT. The former is standard whereas the

latter is proprietary in T-SQL. The CAST function’s syntax is

CAST(source\_expression AS target\_type. For example, CAST(‘100’ AS

INT) converts the source character string constant to the target integer value

100. The CONVERT function is handy when you need to specify a style for

the conversion. Its syntax is CONVERT(target\_type, source\_expression [,

style\_number])

For instance,

when converting a character string to a date and time type or the other way

around, you can specify the style number to avoid ambiguity in case the form

you use is considered language dependent. As an example, the expression

CONVERT(DATE, ‘01/02/2017’, 101) converts the input string to a date

using the U.S. style, meaning January 2, 2017. The expression

CONVERT(DATE, ‘01/02/2017’, 103) uses the British/French style,

meaning February 1, 2017.

The PARSE function is an alternative to CONVERT when you want to

parse a character string input to a target type, but instead of using cryptic

style numbers, it uses a more user-friendly .NET culture name. For instance,

the expression PARSE(‘01/02/2017’ AS DATE USING ‘en-US’) uses the

English US culture, parsing the input as a date meaning January 2, 2017. The

expression PARSE(‘01/02/2017’ AS DATE USING ‘en-GB’) uses the

English Great Britain culture, parsing the input as a date meaning February 1,

2017. Note though that this function is significantly slower than CONVERT,

so I personally stay away from using it.

One of the problems with CAST, CONVERT, and PARSE is that if the

function fails to convert a value within a query, the whole query fails and

stops processing. As an alternative to these functions, T-SQL supports the

TRY\_CAST, TRY\_CONVERT, and TRY\_PARSE functions, which behave

the same as their counterparts when the conversion is valid, but return a

NULL instead of failing when the conversion isn’t valid. As an example, run

the following code to try and convert two strings to dates using the

CONVERT function:

SELECT CONVERT(DATE, '14/02/2017', 101) AS col1,

CONVERT(DATE, '02/14/2017', 101) AS col2;

The first value doesn’t convert successfully and therefore this code fails.

Use the TRY\_CONVERT function instead of CONVERT, like so:

SELECT TRY\_CONVERT(DATE, '14/02/2017', 101) AS col1,

TRY\_CONVERT(DATE, '02/14/2017', 101) AS col2;

This time the code doesn’t fail, but the first expression returns a NULL, as

the following output shows:

col1 col2

---------- ----------

NULL 2017-02-14

Lastly, the FORMAT function is an alternative to the CONVERT function

when you want to format an input expression of some type as a character

string, but instead of using cryptic style numbers, you specify a .NET format

string and culture, if relevant. For instance, to format an input date and time

value, such as now, as a character string using the form ‘yyyy-MM-dd’, use

the expression: FORMAT(SYSDATETIME(), ‘yyyy-MM-dd’).

### Date and time functions

T-SQL supports a number of date and time functions that allow you to

manipulate your date and time data.

**Current date and time**

One important category of functions is the category that returns the current

date and time.

The functions in this category are GETDATE, CURRENT\_TIMESTAMP,

GETUTCDATE, SYSDATETIME, SYSUTCDATETIME, and

SYSDATETIMEOFFSET. GETDATE is T-SQL–specific, returning the

current date and time in the SQL Server instance you’re connected to as a

DATETIME data type. CURRENT\_TIMESTAMP is the same, only it’s

standard, and hence the recommended one to use. SYSDATETIME and

SYSDATETIMEOFFSET are similar, only returning the values as the more

precise DATETIME2 and DATETIMEOFFSET types (including the time

zone offset from UTC), respectively. Note that there are no built-in functions

to return the current date and the current time. To get such information,

simply cast the SYSDATETIME function to DATE or TIME, respectively.

For example, to get the current date, use CAST(SYSDATETIME() AS

DATE). The GETUTCDATE function returns the current date and time in

UTC terms as a DATETIME type, and SYSUTCDATETIME does the same,

only returning the result as the more precise DATETIME2 type.

**Date and time parts**

This section covers date and time functions that either extract a part from a

date and time value (like DATEPART) or construct a date and time value

from parts (like DATEFROMPARTS).

Using the DATEPART function, you can extract from an input date and

time value a desired part, such as a year, minute, or nanosecond, and return

the extracted part as an integer. For example, the expression

DATEPART(month, ‘20170212’) returns 2. T-SQL provides the functions

YEAR, MONTH, and DAY as abbreviations to DATEPART, not requiring

you to specify the part. The DATENAME function is similar to DATEPART,

only it returns the name of the part as a character string, as opposed to the

integer value. Note that the function is language dependent. That is, if the

effective language in your session is us\_english, the expression

DATENAME(month, ‘20170212’) returns ‘February’, but for Italian, it

returns ‘febbraio.'

T-SQL provides a set of functions that construct a desired date and time

value from its numeric parts. You have such a function for each of the six

available date and time types: DATEFROMPARTS,

DATETIME2FROMPARTS, DATETIMEFROMPARTS,

DATETIMEOFFSETFROMPARTS, SMALLDATETIMEFROMPARTS,

and TIMEFROMPARTS. For example, to build a DATE value from its parts,

you would use an expression such as DATEFROMPARTS(2017, 02, 12).

Finally, the EOMONTH function computes the respective end of month

date for the input date and time value. For example, suppose that today was

February 12, 2017. The expression EOMONTH(SYSDATETIME()) would

then return the date ‘2017-02-29’. This function supports a second optional

input indicating how many months to add to the result (or subtract if

negative).

**Add and diff functions**

T-SQL supports addition and difference date and time functions called

DATEADD and DATEDIFF.

DATEADD is a very commonly used function. With it, you can add a

requested number of units of a specified part to a specified date and time

value. For example, the expression DATEADD(year, 1, ‘20170212’) adds

one year to the input date February 12, 2017.

DATEDIFF is another commonly used function; it returns the difference in

terms of a requested part between two date and time values. For example, the

expression DATEDIFF(day, ‘20160212’, ‘20170212’) computes the

difference in days between February 12, 2016 and February 12, 2017,

returning the value 366. Note that this function looks only at the parts from

the requested one and above in the date and time hierarchy—not below. For

example, the expression DATEDIFF(year, ‘20161231’, ‘20170101’) looks

only at the year part, and hence returns 1. It doesn’t look at the month and

day parts of the values.

The DATEDIFF function returns a value of an INT type. If the difference

doesn’t fit in a four-byte integer, use the DATEDIFF\_BIG function instead.

This function returns the result as a BIGINT type.

### Character functions

T-SQL was not really designed to support very sophisticated character string

manipulation functions, so you won’t find a very large set of such functions.

This section describes the character string functions that T-SQL does support,

arranged in categories.

**Concatenation**

Character string concatenation is a very common need. T-SQL supports two

ways to concatenate strings—one with the plus (+) operator, and another with

the CONCAT function.

Here’s an example for concatenating strings in a query by using the +

operator:

SELECT empid, country, region, city,

country + N', ' + region + N', ' + city AS location

FROM HR.Employees;

When any of the inputs is NULL, the + operator returns a NULL. If you want to substitute

a NULL with an empty string, there are a number of ways for you to do this

programmatically. One option is to use ISNULL or COALESCE functions to

replace a NULL with an empty string. For example, in this data, only region

can be NULL, so you can use the following query to replace a comma plus

region with an empty string when region is NULL:

SELECT empid, country, region, city,

country + ISNULL(N', ' + region, N'') + N', ' + city AS

location

FROM HR.Employees;

Another option is to use the CONCAT function which, unlike the +

operator, substitutes a NULL input with an empty string. Here’s how the

query looks:

SELECT empid, country, region, city,

CONCAT(country, N', ' + region, N', ' + city) AS

location

FROM HR.Employees;

**Substring extraction and position**

This section covers functions that you can use to extract a substring from a

string, and identify the position of a substring within a string.

With the SUBSTRING function, you can extract a substring from a string

given as the first argument, starting with the position given as the second

argument, and a length given as the third argument. For example, the

expression SUBSTRING(‘abcde’, 1, 3) returns ‘abc’. If the third argument is

greater than what would get you to the end of the string, the function doesn’t

fail; instead, it just extracts the substring until the end of the string.

The LEFT and RIGHT functions extract a requested number of characters

from the left and right ends of the input string, respectively. For example,

LEFT(‘abcde’, 3) returns ‘abc’ and RIGHT(‘abcde’, 3) returns ‘cde’.

The CHARINDEX function returns the position of the first occurrence of

the string provided as the first argument within the string provided as the

second argument. For example, the expression CHARINDEX(‘ ‘,’Inigo

Montoya’) looks for the first occurrence of a space in the second input,

returning 6 in this example. Note that you can provide a third argument

indicating to the function the position where to start looking.

You can combine, or nest, functions in the same expression. For example,

suppose you query a table with an attribute called fullname formatted as

‘<first> <last>’, and you need to write an expression that extracts the first

name part. You can use the following expression:

LEFT(fullname, CHARINDEX(' ', fullname) - 1)

T-SQL also supports a function called PATINDEX that, like

CHARINDEX, you can use to locate the first position of a string within

another string. But whereas with CHARINDEX you’re looking for a constant

string, with PATINDEX you’re looking for a pattern. The pattern is formed

very similar to the LIKE patterns that you’re probably familiar with, where

you use wildcards like % for any string, \_ for a single character, and square

brackets ([]) representing a single character from a certain list or range.

As an

example, the expression PATINDEX(‘%[0-9]%’, ‘abcd123efgh’) looks for

the first occurrence of a digit (a character in the range 0–9) in the second

input, returning the position 5 in this case.

**String length**

T-SQL provides two functions that you can use to measure the length of an

input value—LEN and DATALENGTH.

The LEN function returns the length of an input string in terms of the

number of characters. Note that it returns the number of characters, not bytes,

whether the input is a regular character or Unicode character string. For

example, the expression LEN(N’xyz’) returns 3. If there are any trailing

spaces, LEN removes them.

The DATALENGTH function returns the length of the input in terms of

number of bytes. This means, for example, that if the input is a Unicode

character string, it will count 2 bytes per character. For example, the

expression DATALENGTH(N’xyz’) returns 6. Note also that, unlike LEN,

the DATALENGTH function doesn’t remove trailing spaces.

**String alteration**

T-SQL supports a number of functions that you can use to apply alterations to

an input string. Those are REPLACE, REPLICATE, and STUFF.

With the REPLACE function, you can replace in an input string provided

as the first argument all occurrences of the string provided as the second

argument, with the string provided as the third argument. For example, the

expression REPLACE(‘.1.2.3.’, ‘.’, ‘/’) substitutes all occurrences of a dot (.)

with a slash (/), returning the string ‘/1/2/3/’.

The REPLICATE function allows you to replicate an input string a

requested number of times. For example, the expression REPLICATE(‘0’,

10) replicates the string ‘0’ ten times, returning ‘0000000000’.

The STUFF function operates on an input string provided as the first

argument; then, from the character position indicated as the second argument,

deletes the number of characters indicated by the third argument. Then it

inserts in that position the string specified as the fourth argument. For

example, the expression STUFF(‘,x,y,z’, 1, 1, ‘’) removes the first character

from the input string, returning ‘x,y,z’.

**Formatting**

This section covers functions that you can use to apply formatting options to

an input string. Those are the UPPER, LOWER, LTRIM, RTRIM, and

FORMAT functions.

The first four functions are self-explanatory (uppercase form of the input,

lowercase form of the input, input after removal of leading spaces, and input

after removal of trailing spaces). Note that there’s no TRIM function that

removes both leading and trailing spaces; to achieve this, you need to nest

one function call within another, as in RTRIM(LTRIM(<input>)).

As mentioned earlier, with the FORMAT function, you can format an input

value based on a .NET format string. I demonstrated an example with date

and time values. As another example, this time with numeric values, the

expression FORMAT(1759, ‘0000000000’) formats the input number as a

character string with a fixed size of 10 characters with leading zeros,

returning ‘0000001759’. The same thing can be achieved with the format

string ‘d10’, meaning decimal value with 10 digits, with the expression

FORMAT(1759, ‘d10’).

### System functions

System functions return information about various aspects of the system.

**The @@ROWCOUNT and ROWCOUNT\_BIG functions**

The @@ROWCOUNT function is a very popular function that returns the

number of rows affected by the last statement that you executed. It’s very

common to use it to check if the previous statement affected any rows by

checking that the function’s result is zero or greater than zero. For example,

the following code queries the input employee row, and prints a message if

the requested employee was not found:

DECLARE @empid AS INT = 10;

SELECT empid, firstname, lastname

FROM HR.Employees

WHERE empid = @empid;

IF @@ROWCOUNT = 0

PRINT CONCAT('Employee ', CAST(@empid AS VARCHAR(10)), ' was not found.');

**Arithmetic operators and aggregate functions**

T-SQL supports the four classic arithmetic operators + (add), - (subtract), \*

(multiply), / (divide), as well as the fifth operator % (modulo). The last

computes the remainder of an integer division. T-SQL also supports

aggregate functions, which you apply to a set of rows, and get a single value

back.

**Arithmetic operators**

For the most part, work with these arithmetic operators is intuitive. They

follow classic arithmetic operator precedence rules, which say that

multiplication, division and modulo precede addition and subtraction. To

change precedence of operations, use parentheses because they precede

arithmetic operators. For example, consider the following expression:

SELECT 2 + 3 \* 2 + 10 / 2;

It is equivalent to the following expression:

SELECT 2 + (3 \* 2) + (10 / 2);

The result of this expression is 13.

If you want to evaluate the operations from left to right, you need to use

parentheses as follows:

SELECT ((2 + 3) \* 2 + 10) / 2;

This expression evaluates to 10.

The data types of the operands in an arithmetic computation determine the

data type of the result. If the operands are integers, the result of arithmetic

operations is an integer. With this in mind, consider the following expression:

SELECT 9 / 2;

With integer division, the result of this expression is 4 and not 4.5.

Obviously, when using constants, you can simply specify numeric values

instead of integer values to get numeric division; however, when the

operands are integer columns or parameters, but you need numeric division,

you have two options. One option is to explicitly cast the operands to a

numeric type with the appropriate precision and scale as follows:

DECLARE @p1 AS INT = 9, @p2 AS INT = 2;

SELECT CAST(@p1 AS NUMERIC(12, 2)) / CAST(@p2 AS

NUMERIC(12, 2));

The result of this expression is 4.500000000000000. The operation here is division. The applicable formula

to calculate the precision here is p1 - s1 + s2 + max(6, s1 + p2 + 1), which

when applied to our inputs results in 27. The formula for the scale is max(6,

s1 + p2 + 1), which in this case results in 15.

Another option is to multiply the first operand by a numeric constant, and

this way force implicit conversion of both the first and the second operands to

a numeric type as follows:

DECLARE @p1 AS INT = 9, @p2 AS INT = 2;

SELECT 1.0 \* @p1 / @p2;

### Aggregate functions

An aggregate function is a function that you apply to a set of rows and get a

single value back. T-SQL supports aggregate functions such as SUM,

COUNT, MIN, MAX, AVG and others.

Aggregate functions ignore NULL inputs when applied to an expression.

The COUNT(\*) aggregate just counts rows, and returns the result as an INT

value. Use COUNT\_BIG to return the row count as a BIGINT value. If you

want to apply an aggregate function to distinct values, add the DISTINCT

clause, as in COUNT(DISTINCT custid).

You can apply aggregate functions in explicit grouped queries as the

following example shows:

SELECT empid, SUM(qty) AS totalqty

FROM Sales.OrderValues

GROUP BY empid;

An aggregate function can also be applied as a scalar aggregate in an

implied grouped query. The presence of the aggregate function causes the

query to be considered a grouped one, as in the following example:

SELECT SUM(qty) AS totalqty FROM Sales.OrderValues;

This query returns the grand total quantity 51,317.

Like with arithmetic operators, also with aggregate functions like AVG,

the data type of the input determines the data type of the result. For instance,

the following query produces an integer average:

SELECT AVG(qty) AS avgqty FROM Sales.OrderValues;

The result of this average is the integer 61.

You can use the two aforementioned options that I described for arithmetic

operations to get a numeric average. Either explicitly cast the input to a

numeric type as follows:

SELECT AVG(CAST(qty AS NUMERIC(12, 2))) AS avgqty FROM

Sales.OrderValues;

Or implicitly as follows:

SELECT AVG(1.0 \* qty) AS avgqty FROM Sales.OrderValues;

This time you get the result 61.827710.

If you’re wondering why the scale of the result value here is 6 digits, the

AVG function is handled internally as a sum divided by a count. The scale of

the input expression (1.0 \* qty) is the sum of the scales of the operands (1 for

1.0 and 0 for the integer qty), which in our case is 1. The sum aggregate’s

scale is the maximum scale among the input values, which in our case is 1.

Then the scale of the result of the division between the sum and the count is

based on the formula max(6, s1 + p2 + 1), which in our case is 6.

## **Modify data**

The T-SQL support for data manipulation language (DML) includes both

statements that retrieve data (SELECT) and statements that modify data

(INSERT, UPDATE, DELETE, TRUNCATE TABLE, and MERGE). The

previous skills focused on data retrieval; this skill focuses on data

modification.

### Inserting data

T-SQL supports a number of different methods that you can use to insert data

into your tables. Those include statements like INSERT VALUES, INSERT

SELECT, INSERT EXEC, and SELECT INTO. This section covers these

statements and demonstrates how to use them through examples.

Some of the of the code examples in this section use a table called

Sales.MyOrders. Use the following code to create such a table in the sample

database TSQLV4:

USE TSQLV4;

DROP TABLE IF EXISTS Sales.MyOrders;

GO

CREATE TABLE Sales.MyOrders

(

orderid INT NOT NULL IDENTITY(1, 1)

CONSTRAINT PK\_MyOrders\_orderid PRIMARY KEY,

custid INT NOT NULL,

empid INT NOT NULL,

orderdate DATE NOT NULL

CONSTRAINT DFT\_MyOrders\_orderdate DEFAULT

(CAST(SYSDATETIME() AS DATE)),

shipcountry NVARCHAR(15) NOT NULL,

freight MONEY NOT NULL

);

Observe that the orderid column has an identity property defined with a

seed 1 and an increment 1. This property generates the values in this column

automatically when rows are inserted. As an alternative to the identity

property you can use a sequence object to generate surrogate keys.

Also observe that the orderdate column has a default constraint with an

expression that returns the current system’s date.

#### CREATE TABLE (Transact-SQL) IDENTITY (Property)

Syntax:

IDENTITY [ (seed , increment) ]

**Arguments**

seed  
Is the value that is used for the very first row loaded into the table.

increment  
Is the incremental value that is added to the identity value of the previous row that was loaded.

You must specify both the seed and increment or neither. If neither is specified, the default is (1,1).

**Remarks**

Identity columns can be used for generating key values. The identity property on a column guarantees the following:

* Each new value is generated based on the current seed & increment.
* Each new value for a particular transaction is different from other concurrent transactions on the table.

The identity property on a column does not guarantee the following:

* **Uniqueness of the value** - Uniqueness must be enforced by using a **PRIMARY KEY** or **UNIQUE** constraint or **UNIQUE** index.
* **Consecutive values within a transaction** - A transaction inserting multiple rows is not guaranteed to get consecutive values for the rows because other concurrent inserts might occur on the table. If values must be consecutive then the transaction should use an exclusive lock on the table or use the **SERIALIZABLE** isolation level.
* **Consecutive values after server restart or other failures** -SQL Server might cache identity values for performance reasons and some of the assigned values can be lost during a database failure or server restart. This can result in gaps in the identity value upon insert. If gaps are not acceptable then the application should use its own mechanism to generate key values. Using a sequence generator with the **NOCACHE** option can limit the gaps to transactions that are never committed.
* **Reuse of values** - For a given identity property with specific seed/increment, the identity values are not reused by the engine. If a particular insert statement fails or if the insert statement is rolled back then the consumed identity values are lost and will not be generated again. This can result in gaps when the subsequent identity values are generated.

These restrictions are part of the design in order to improve performance, and because they are acceptable in many common situations. If you cannot use identity values because of these restrictions, create a separate table holding a current value and manage access to the table and number assignment with your application.

If a table with an identity column is published for replication, the identity column must be managed in a way that is appropriate for the type of replication used. For more information, see [Replicate Identity Columns](https://docs.microsoft.com/en-us/sql/relational-databases/replication/publish/replicate-identity-columns?view=sql-server-ver15).

Only one identity column can be created per table.

**Example:**

USE AdventureWorks2012;

IF OBJECT\_ID ('dbo.new\_employees', 'U') IS NOT NULL

DROP TABLE new\_employees;

GO

CREATE TABLE new\_employees

(

id\_num int IDENTITY(1,1),

fname varchar (20),

minit char(1),

lname varchar(30)

);

INSERT new\_employees

(fname, minit, lname)

VALUES

('Karin', 'F', 'Josephs');

INSERT new\_employees

(fname, minit, lname)

VALUES

('Pirkko', 'O', 'Koskitalo');

#### INSERT VALUES

With the INSERT VALUES statement, you can insert one or more rows into

a target table based on value expressions. Here’s an example for a statement

inserting one row into the Sales.MyOrderValues table:

INSERT INTO Sales.MyOrders(custid, empid, orderdate,

shipcountry, freight)

VALUES(2, 19, '20170620', N'USA', 30.00);

Specifying the target column names after the table name is optional but

considered a best practice. That’s because it enables you to control the source

value to target column association, irrespective of the order in which the

columns were defined in the table.

Without the target column list, you must specify the values in column

definition order. If the underlying table definition changes but the INSERT

statements aren’t modified accordingly, this can result in either errors, or

worse, values written to the wrong columns.

The INSERT VALUES statement does not specify a value for a column

with an identity property because the property generates the value for the

column automatically. Observe that the previous statement doesn’t specify

the orderid column. If you do want to provide your own value instead of

letting the identity property do it for you, you need to first turn on a session

option called IDENTITY\_INSERT, as follows:

SET IDENTITY\_INSERT <table> ON;

When you’re done, you need to remember to turn it off.

Note that in order to use this option, you need quite strong permissions;

you need to be the owner of the table or have ALTER permissions on the

table.

Besides using the identity property, there are other ways for a column to

get its value automatically in an INSERT statement. A column can have a

default constraint associated with it like the orderdate column in the

Sales.MyOrders table. If the INSERT statement doesn’t specify a value for

the column explicitly, SQL Server will use the default expression to generate

that value. For example, the following statement doesn’t specify a value for

orderdate, and therefore SQL Server uses the default expression:

INSERT INTO Sales.MyOrders(custid, empid, shipcountry,

freight)

VALUES(3, 11, N'USA', 10.00);

Another way to achieve the same behavior is to specify the column name

in the names list and the keyword DEFAULT in the respective element in the

VALUES list. Here’s an INSERT example demonstrating this:

INSERT INTO Sales.MyOrders(custid, empid, orderdate,

shipcountry, freight)

VALUES(3, 17, DEFAULT, N'USA', 30.00);

If you don’t specify a value for a column, SQL Server first checks whether

the column gets its value automatically—for example, from an identity

property or a default constraint. If that’s not the case, SQL Server checks

whether the column allows NULLs, in which case it assumes a NULL. If

that’s not the case, SQL Server generates an error.

The INSERT VALUES statement doesn’t limit you to inserting only one

row; rather, it enables you to insert multiple rows. Simply separate the rows

with commas, as follows:

INSERT INTO Sales.MyOrders(custid, empid, orderdate,

shipcountry, freight) VALUES

(2, 11, '20170620', N'USA', 50.00),

(5, 13, '20170620', N'USA', 40.00),

(7, 17, '20170620', N'USA', 45.00);

Note that the entire statement is considered one transaction, meaning that if

any row fails to enter the target table, the entire statement fails and no row is

inserted.

To see the result of running all INSERT examples in this section, query the

table by using the following query:

SELECT \* FROM Sales.MyOrders;

#### INSERT SELECT

The INSERT SELECT statement inserts the result set returned by a query

into the specified target table. As with INSERT VALUES, the INSERT

SELECT statement supports optionally specifying the target column names.

Also, you can omit columns that get their values automatically from an

identity property, default constraint, or when allowing NULLs.

As an example, the following code inserts into the Sales.MyOrders table

the result of a query against Sales.Orders returning orders shipped to

customers in Norway:

SET IDENTITY\_INSERT Sales.MyOrders ON;

INSERT INTO Sales.MyOrders(orderid, custid, empid,

orderdate, shipcountry, freight)

SELECT orderid, custid, empid, orderdate,

shipcountry, freight

FROM Sales.Orders

WHERE shipcountry = N'Norway';

SET IDENTITY\_INSERT Sales.MyOrders OFF;

The code turns on the IDENTITY\_INSERT option against Sales.MyOrders

in order to use the original order IDs and not let the identity property generate

those.

Setting IDENTITY\_INSERT to OFF causes the current identity value of

the table to be set to the current maximum value in the identity column. In

our example, the current identity value was set to 11015. If you now add

another row to the table, the order ID will be set to 11016.

#### INSERT EXEC

With the INSERT EXEC statement, you can insert the result set (or sets)

returned by a dynamic batch or a stored procedure into the specified target

table. Much like the INSERT VALUES and INSERT SELECT statements,

INSERT EXEC supports specifying an optional target column list, and allows

omitting columns that accept their values automatically.

To demonstrate the INSERT EXEC statement, the following example uses

a procedure called Sales.OrdersForCountry, which accepts a ship country as

input and returns orders shipped to the input country. Run the following code

to create the Sales.OrdersForCountry procedure:

DROP PROC IF EXISTS Sales.OrdersForCountry;

GO

CREATE PROC Sales.OrdersForCountry

@country AS NVARCHAR(15)

AS

SELECT orderid, custid, empid, orderdate, shipcountry,

freight

FROM Sales.Orders

WHERE shipcountry = @country;

GO

Run the following code to invoke the stored procedure with Portugal as the

input country, and insert the result of the procedure into the Sales.MyOrders

table:

SET IDENTITY\_INSERT Sales.MyOrders ON;

INSERT INTO Sales.MyOrders(orderid, custid, empid,

orderdate, shipcountry, freight)

EXEC Sales.OrdersForCountry

@country = N'Portugal';

SET IDENTITY\_INSERT Sales.MyOrders OFF;

Here as well, the code turns on the IDENTITY\_INSERT option against the

target table so that the INSERT statement can specify the values for the

identity column instead of letting the property assign those.

INSERT EXEC works even when the source dynamic batch or stored

procedure has more than one query. But that’s as long as all queries return

result sets that are compatible with the target table definition.

#### SELECT INTO

The SELECT INTO statement involves a query (the SELECT part) and a

target table (the INTO part). The statement creates the target table based on

the definition of the source and inserts the result rows from the query into

that table. The statement copies from the source some aspects of the data

definition like the column names, types, nullability, and identity property, in

addition to the data itself. Certain aspects of the data definition aren’t copied

like indexes, constraints, triggers, permissions, and others. If you want to

include these aspects, you need to script them from the source and apply

them to the target.

The following code shows an example for a SELECT INTO statement that

queries the Sales. Orders table returning orders shipped to Norway, creates a

target table called Sales.MyOrders, and stores the query’s result in the target

table:

DROP TABLE IF EXISTS Sales.MyOrders;

SELECT orderid, custid, orderdate, shipcountry, freight

INTO Sales.MyOrders

FROM Sales.Orders

WHERE shipcountry = N'Norway';

As mentioned, the SELECT INTO statement creates the target table based

on the definition of the source. You don’t have direct control over the

definition of the target. If you want target columns to be defined different

than the source, you need to apply some manipulation.

For example, the source orderid column has an identity property, and

hence the target column is defined with an identity property as well. If you

want the target column not to have the property, you need to apply some kind

of manipulation, like orderid + 0 AS orderid. Note that after you apply

manipulation, the target column definition allows NULLs. If you want the

target column to be defined as not allowing NULLs, you need to use the

ISNULL function, returning a non-NULL value in case the source is a

NULL. This is just an artificial expression that lets SQL Server know that the

outcome cannot be NULL and, hence, the column can be defined as not

enabling NULLs. For example, you could use an expression such as this one:

ISNULL(orderid + 0, -1) AS orderid.

Similarly, the source custid column is defined in the source as allowing

NULLs. To make the target column be defined as NOT NULL, use the

expression ISNULL(custid, -1) AS custid.

If you want the target column’s type to be different than the source, you

can use the CAST or CONVERT functions. But remember that in such a

case, the target column definition enables NULLs even if the source column

disallowed NULLs, because you applied manipulation to the source column.

As with the previous examples, you can use the ISNULL function to make

SQL Server define the target column as not enabling NULLs. For example, to

convert the orderdate column from its source type DATETIME to DATE in

the target, and disallow NULLs, use the expression

ISNULL(CAST(orderdate AS DATE), ‘19000101’) AS orderdate.

To put it all together, the following code uses a query similar to the

previous example, only defining the orderid column without the identity

property as NOT NULL, the custid column as NOT NULL, and the orderdate

column as DATE NOT NULL:

DROP TABLE IF EXISTS Sales.MyOrders;

SELECT

ISNULL(orderid + 0, -1) AS orderid, -- get rid of

-- identity property

-- make column NOT NULL

ISNULL(custid, -1) AS custid, -- make column NOT NULL

empid,

ISNULL(CAST(orderdate AS DATE), '19000101') AS

orderdate,

shipcountry, freight

INTO Sales.MyOrders

FROM Sales.Orders

WHERE shipcountry = N'Norway';

Remember that SELECT INTO does not copy constraints from the source

table, so if you need those, it’s your responsibility to define them in the

target. For example, the following code defines a primary key constraint in

the target table:

ALTER TABLE Sales.MyOrders

ADD CONSTRAINT PK\_MyOrders PRIMARY KEY(orderid);

One of the benefits of using SELECT INTO is that when the database’s

recovery model is not set to full, but instead to either simple or bulk logged,

the statement uses an optimized logging mode. This can potentially result in a

faster insert compared to when full logging is used.

Also, remember that SELECT INTO involves both creating a table and

populating it with data. This means that both the metadata related to the target

table and the data are exclusively locked until the SELECT INTO transaction

finishes. As a result, you can run into blocking situations due to conflicts

related to both data and metadata access.

Generate new table without data, just the structure of another table.

SELECT TOP 0

Order\_Id = ordered

, Cust\_Id = custid

, Order\_Date = orderdate

, Ship\_Country = shipcountry

, freight

INTO Sales.MyOrders

FROM Sales.Orders

When you are done, run the following code for cleanup:

DROP TABLE IF EXISTS Sales.MyOrders;

### UPDATE statement

T-SQL supports the standard UPDATE statement, which enables you to

update existing rows in a table. The standard UPDATE statement has the

following form:

UPDATE <target table>

SET <col 1> = <expression 1>,

...,

<col n> = <expression n>

WHERE <predicate>;

You specify the target table name in the UPDATE clause. If you want to

filter a subset of rows, you indicate a WHERE clause with a predicate. Only

rows for which the predicate evaluates to true are updated. Rows for which

the predicate evaluates to false or unknown are not affected. An UPDATE

statement without a WHERE clause affects all rows. You assign values to

target columns in the SET clause. The source expressions can involve

columns from the table, in which case their values before the update are used.

As an example, you modify rows in the Sales.MyOrderDetails table

representing order lines associated with order 10251. First, query those rows

to examine their state prior to the update:

SELECT \*

FROM Sales.MyOrderDetails

WHERE orderid = 10251;

You get the following output:

orderid productid unitprice qty discount

----------- ----------- --------------------- ------ -----

----

10251 22 16.80 6 0.050

10251 57 15.60 15 0.050

10251 65 16.80 20 0.000

The following code demonstrates an UPDATE statement that adds a five

percent discount to these order lines:

UPDATE Sales.MyOrderDetails

SET discount += 0.05

WHERE orderid = 10251;

Notice the use of the compound assignment operator discount += 0.05.

This assignment is equivalent to discount = discount + 0.05. T-SQL supports

such enhanced operators for all binary assignment operators: += (add), -=

(subtract), \*= (multiply), /= (divide), %= (modulo), &= (bitwise and), |=

(bitwise or), ^= (bitwise xor), += (concatenate).

Query again the order lines associated with order 10251 to see their state

after the update:

SELECT \*

FROM Sales.MyOrderDetails

WHERE orderid = 10251;

You get the following output showing an increase of five percent in the

discount:

orderid productid unitprice qty discount

----------- ----------- --------------------- ------ -----

----

10251 22 16.80 6 0.100

10251 57 15.60 15 0.100

10251 65 16.80 20 0.050

Use the following code to reduce the discount in the aforementioned order

lines by five percent:

UPDATE Sales.MyOrderDetails

SET discount -= 0.05

WHERE orderid = 10251;

These rows should now be back to their original state before the first

update.

**UPDATE based on join**

Standard SQL doesn’t support using joins in UPDATE statements, but TSQL

does. The idea is that you might want to update rows in a table, and

refer to related rows in other tables for filtering and assignment purposes.

As an example, suppose that you want to add a five percent discount to

order lines associated with orders placed by customers from Norway. The

rows you need to modify are in the Sales.MyOrderDetails table. But the

information you need to examine for filtering purposes is in rows in the

Sales.MyCustomers table. In order to match a customer with its related order

lines, you need to join Sales.MyCustomers with Sales.MyOrders, and then

join the result with Sales.MyOrderDetails. Note that it’s not sufficient to

examine the shipcountry column in Sales. MyOrders; instead, you must

check the country column in Sales.MyCustomers.

Based on your knowledge of joins, if you wanted to write a SELECT

statement returning the order lines that are the target for the update, you

would write a query like the following one:

SELECT OD.\*

FROM Sales.MyCustomers AS C

INNER JOIN Sales.MyOrders AS O

ON C.custid = O.custid

INNER JOIN Sales.MyOrderDetails AS OD

ON O.orderid = OD.orderid

WHERE C.country = N'Norway';

This query identifies 16 order lines, all currently with a discount value of

0.000.

In order to perform the desired update, simply replace the SELECT clause

from the last query with an UPDATE clause, indicating the alias of the table

that is the target for the

UPDATE (OD in this case), and the assignment in the SET clause, as

follows:

UPDATE OD

SET OD.discount += 0.05

FROM Sales.MyCustomers AS C

INNER JOIN Sales.MyOrders AS O

ON C.custid = O.custid

INNER JOIN Sales.MyOrderDetails AS OD

ON O.orderid = OD.orderid

WHERE C.country = N'Norway';

Note that you can refer to elements from all tables involved in the

statement in the source expressions, but you’re allowed to modify only one

target table at a time. Rerun the SELECT query to examine the affected order

lines, and you find that they now have a discount value of 0.050.

To get the previous order lines back to their original state, run an UPDATE

statement that reduces the discount by five percent:

UPDATE OD

SET OD.discount -= 0.05

FROM Sales.MyCustomers AS C

INNER JOIN Sales.MyOrders AS O

ON C.custid = O.custid

INNER JOIN Sales.MyOrderDetails AS OD

ON O.orderid = OD.orderid

WHERE C.country = N'Norway';

**Nondeterministic UPDATE**

You should be aware that the proprietary T-SQL UPDATE syntax based on

joins could be nondeterministic. The statement is nondeterministic when

multiple source rows match one target row. Unfortunately, in such a case,

SQL Server doesn’t generate an error or even a warning. Instead, SQL Server

silently performs a nondeterministic UPDATE where it arbitrarily chooses

one of the source rows.

As an example, the following query matches customers with their related

orders, returning the customers’ postal codes, as well as shipping postal codes

from related orders:

SELECT C.custid, C.postalcode, O.shippostalcode

FROM Sales.MyCustomers AS C

INNER JOIN Sales.MyOrders AS O

ON C.custid = O.custid

ORDER BY C.custid;

This query generates the following output:

custid postalcode shippostalcode

----------- ---------- --------------

1 10092 10154

1 10092 10156

1 10092 10155

1 10092 10154

1 10092 10154

1 10092 10154

2 10077 10182

2 10077 10181

...

Each customer row is repeated in the output for each matching order. This

means that each customer’s only postal code is repeated in the output as

many times as the number of matching orders. It’s important for the purposes

of this example to remember that there is only one postal code per customer.

The shipping postal code is associated with an order, so as you can realize,

there can be multiple distinct shipping postal codes per customer. With this in

mind, consider the following UPDATE statement:

UPDATE C

SET C.postalcode = O.shippostalcode

FROM Sales.MyCustomers AS C

INNER JOIN Sales.MyOrders AS O

ON C.custid = O.custid;

There are 89 customers that have matching orders—some with multiple

matches. SQL Server doesn’t generate an error though; instead it arbitrarily

chooses for each target row which source row is to be considered for the

update, returning the following message:

(89 row(s) affected)

Query the rows from the Sales.Customers table after the update:

SELECT custid, postalcode

FROM Sales.MyCustomers

ORDER BY custid;

This generated the following output on one system, but your results could

be different:

custid postalcode

----------- ----------

1 10154

2 10182

...

(91 row(s) affected)

Note that the table has 91 rows, but because only 89 of those customers

have related orders, the previous UPDATE statement affected 89 rows.

As to which source row gets chosen for each target row, the choice isn’t

exactly random, but arbitrary; in other words, it’s optimization-dependent. At

any rate, you do not have any logical elements in the language to control this

choice. The recommended approach is simply not to use such

nondeterministic UPDATE statements, rather have logic in your solution to

break ties.

For example, suppose that you want to update the customer’s postal code

with the shipping postal code from the customer’s first order (based on the

sort order of orderdate, orderid). You can achieve this using the following

code:

UPDATE C

SET C.postalcode = A.shippostalcode

FROM Sales.MyCustomers AS C

CROSS APPLY (SELECT TOP (1) O.shippostalcode

FROM Sales.MyOrders AS O

WHERE O.custid = C.custid

ORDER BY orderdate, orderid) AS A;

The APPLY operator applies a subquery that identifies its most recent order.

SQL Server generates the following message:

(89 row(s) affected)

Query the Sales.MyCustomers table after the update:

SELECT custid, postalcode

FROM Sales.MyCustomers

ORDER BY custid;

You get the following output:

custid postalcode

----------- ----------

1 10154

2 10180

...

(91 row(s) affected)

If you want to use the most-recent order as the source for the update,

simply use descending sort order in both columns: ORDER BY orderdate

DESC, orderid DESC.

**UPDATE with a variable**

Sometimes you need to modify a row and also collect the result of the

modified columns into variables. You can handle such a need with a

combination of UPDATE and SELECT statements, but this would require

two visits to the row. T-SQL supports a specialized UPDATE syntax that

allows achieving the task by using one statement and one visit to the row.

As an example, run the following query to examine the current state of the

order line associated with order 10250 and product 51:

SELECT \*

FROM Sales.MyOrderDetails

WHERE orderid = 10250

AND productid = 51;

This code generates the following output:

orderid productid unitprice qty discount

----------- ----------- --------------------- ------ -----

----

10250 51 42.40 35 0.150

Suppose that you need to modify the row, increasing the discount by five

percent, and collect the new discount into a variable called @newdiscount.

You can achieve this using a single UPDATE statement, as follows.

DECLARE @newdiscount AS NUMERIC(4, 3) = NULL;

UPDATE Sales.MyOrderDetails

SET @newdiscount = discount += 0.05

WHERE orderid = 10250

AND productid = 51;

SELECT @newdiscount;

As you can see, the UPDATE and WHERE clauses are similar to those

you use in normal UPDATE statements. But the SET clause uses the

assignment @newdiscount = discount += 0.05, which is equivalent to using

@newdiscount = discount = discount + 0.05. The statement assigns the result

of discount + 0.05 to discount, and then assigns the result to the variable

@newdiscount. The last SELECT statement in the code returns the new

discount 0.200.

When you’re done, issue the following code to undo the last change:

UPDATE Sales.MyOrderDetails

SET discount -= 0.05

WHERE orderid = 10250

AND productid = 51;

**UPDATE all-at-once**

Earlier in the book as part of the discussion about logical query processing I

explained that expressions that appear in the same logical phase are treated as

a set, in an *all-at-once* manner. The all-at-once concept also has implications

on UPDATE statements. To demonstrate those implications, this section uses

a table called T1. Use the following code to create the table T1 and insert a

row into it:

DROP TABLE IF EXISTS dbo.T1;

CREATE TABLE dbo.T1

(

keycol INT NOT NULL

CONSTRAINT PK\_T1 PRIMARY KEY,

col1 INT NOT NULL,

col2 INT NOT NULL

);

INSERT INTO dbo.T1(keycol, col1, col2) VALUES(1, 100, 0);

Next, examine the following code but don’t run it yet:

DECLARE @add AS INT = 10;

UPDATE dbo.T1

SET col1 += @add, col2 = col1

WHERE keycol = 1;

SELECT \* FROM dbo.T1;

Can you guess what should be the value of col2 in the modified row after

the update? If you guessed 110, you were not thinking of the assignments as a

set, all-at-once. All assignments use the original values of the row as the

source values, irrespective of their order of appearance. So the assignment

col2 = col1 doesn’t get the col1 value after the change, but rather before the

change—namely 100. To verify this, run the previous code.

You get the following output:

keycol col1 col2

----------- ----------- -----------

1 110 100

When you’re done, run the following code for cleanup:

DROP TABLE IF EXISTS dbo.T1;

### **Deleting data**

T-SQL supports two statements that you can use to delete rows from a table:

DELETE and TRUNCATE TABLE.

As a reminder, the sample data involves the tables

Sales.MyCustomers, Sales.MyOrders, and Sales.MyOrderDetails, which are

initially created as copies of the tables Sales.Customers, Sales.Orders, and

Sales.OrderDetails, respectively. Use the following code to recreate tables

and repopulate them with sample data:

DROP TABLE IF EXISTS Sales.MyOrderDetails, Sales.MyOrders,

Sales.MyCustomers;

SELECT \* INTO Sales.MyCustomers FROM Sales.Customers;

ALTER TABLE Sales.MyCustomers

ADD CONSTRAINT PK\_MyCustomers PRIMARY KEY(custid);

SELECT \* INTO Sales.MyOrders FROM Sales.Orders;

ALTER TABLE Sales.MyOrders

ADD CONSTRAINT PK\_MyOrders PRIMARY KEY(orderid);

SELECT \* INTO Sales.MyOrderDetails FROM

Sales.OrderDetails;

ALTER TABLE Sales.MyOrderDetails

ADD CONSTRAINT PK\_MyOrderDetails PRIMARY KEY(orderid,

productid);

#### **DELETE statement**

With the DELETE statement, you can delete rows from a table. You can

optionally specify a predicate to restrict the rows to be deleted. The general

form of a DELETE statement looks like the following:

DELETE FROM <table>

WHERE <predicate>;

If you don’t specify a predicate, all rows from the target table are deleted.

As with unqualified updates, you need to be especially careful about

accidentally deleting all rows by highlighting only the DELETE part of the

statement, missing the WHERE part.

The following example deletes all order lines containing product ID 11

from the Sales.MyOrderDetails table:

DELETE FROM Sales.MyOrderDetails

WHERE productid = 11;

You get a message indicating that 38 rows were affected.

The tables used by the examples in this chapter are very small, but in a

more realistic production environment, the volumes of data are likely to be

much bigger. A DELETE statement is fully logged and as a result, large deletes can take a long time to complete, and much longer to roll back if you need to terminate them.

Such large deletes can cause the transaction log to increase in size

dramatically during the process. They can also result in lock escalation,

meaning that SQL Server escalates fine-grained locks like row or page locks

to a full-blown table lock. Such escalation can result in blocking access to all

table data by other processes.

To prevent the aforementioned problems from happening, you can split

your large delete into smaller chunks. You can achieve this by using a

DELETE statement with a TOP option that limits the number of affected

rows in a loop. Here’s an example for implementing such a solution:

WHILE 1 = 1

BEGIN

DELETE TOP (1000) FROM Sales.MyOrderDetails

WHERE productid = 12;

IF @@rowcount < 1000 BREAK;

END

As you can see, the code uses an infinite loop (WHILE 1 = 1 is always

true). In each iteration, a DELETE statement with a TOP option limits the

number of affected rows to no more than 1,000 at a time. Then the IF

statement checks if the number of affected rows is less than 1,000; in such a

case, the last iteration deleted the last chunk of qualifying rows. After the last

chunk of rows has been deleted, the code breaks from the loop. With this

sample data, there are only 14 qualifying rows in total. So if you run this

code, it is done after one round, break from the loop, and return. But with a

large number of qualifying rows, say, millions, you’d very likely be better off

with such a solution.

#### **TRUNCATE TABLE statement**

TRUNCATE TABLE is an optimized statement that deletes all rows from the

target table or partition. Unlike the DELETE statement, the TRUNCATE

TABLE statement doesn’t support a filter. Also, whereas the DELETE

statement is fully logged and therefore tends to be quite slow, the

TRUNCATE table statement uses an optimized logging mode and therefore

is significantly faster.

For example, the following statement truncates the table Sales.MyOrderDetails:

TRUNCATE TABLE Sales.MyOrderDetails;

Suppose that you had a partitioned table called MyTable and you wanted

to truncate partitions 1, 2 and 11 to 20. You would achieve this with the

following code:

TRUNCATE TABLE MyTable WITH ( PARTITIONS(1, 2, 11 TO 20)

);

Besides the performance difference and the fact that TRUNCATE TABLE

doesn’t support a filter, there are a few additional differences compared to the

DELETE statement:

* You cannot assign direct TRUNCATE TABLE permissions, rather at minimum you need ALTER permission on the target table. A common workaround is to place the TRUNCATE TABLE statement in a module, like a stored procedure, and assign the required permission to the module using the EXECUTE AS clause.
* If there’s a column with an identity property in the target table, DELETE doesn’t reset the property whereas TRUNCATE TABLE does.
* If there are any foreign keys pointing to the target table, a DELETE statement is supported as long as there are no related rows in the referencing table, but a TRUNCATE TABLE statement isn’t. You need to first drop the foreign keys, truncate the table, and then recreate the foreign keys.
* If there are any indexed views based on the table, a DELETE statement is supported whereas a TRUNCATE TABLE statement isn’t.

Clearly, if you need to delete all rows from a table or a partition but leave

the table definition in place, the recommended tool to use is the TRUNCATE

TABLE statement.

**DELETE based on a join**

Much like the proprietary syntax that T-SQL supports for an UPDATE

statement based on a join, T-SQL supports similar syntax for a DELETE

statement based on a join. The idea is to allow you to delete rows from one

table based on the presence of related rows in other tables, with the ability to

apply a filter predicate that is based on attributes in the related tables.

As an example, the following statement deletes orders placed by customers

from the US:

DELETE FROM O

FROM Sales.MyOrders AS O

INNER JOIN Sales.MyCustomers AS C

ON O.custid = C.custid

WHERE C.country = N'USA';

Notice that there are two FROM clauses. The second is mandatory and is

similar to the FROM clause in a SELECT statement. That’s where you apply

table operators like joins. The first FROM clause appears right after the

DELETE clause and is optional. That’s where you specify the target for the

delete. In our case it’s the alias O representing the Sales.MyOrders table.

When you’re done, run the following code for cleanup:

DROP TABLE IF EXISTS Sales.MyOrderDetails, Sales.MyOrders,

Sales.MyCustomers;

### **Merging data**

With the MERGE statement, you can merge data from a source table into a

target table. The statement has many practical uses in both online transaction

processing (OLTP) scenarios and in data warehousing ones. As an example

of an OLTP use case, suppose that you have a table that isn’t updated directly

by your application; instead, you get the delta of changes periodically from

an external system. You first load the delta of changes into a staging table,

and then use the staging table as the source for the merge operation into the

target.

As an example for a data warehousing scenario, suppose that you maintain

aggregated views of the data in your data warehouse. Using the MERGE

statement, you can apply changes that were applied to detail rows into the

aggregated form.

These are just a couple of typical use cases; there are many more. This

lesson describes the MERGE statement and its different options, and

demonstrates its use through examples.

**Using the MERGE statement**

With the MERGE statement, you can merge data from a source table or table

expression into a target table. This statement is mostly standard, with one

proprietary extension by Microsoft of a clause called WHEN NOT

MATCHED BY SOURCE. The general form of the MERGE statement is as

follows:

MERGE INTO <target table> AS TGT

USING <SOURCE TABLE> AS SRC

ON <merge predicate>

WHEN MATCHED [AND <predicate>] -- two clauses allowed:

THEN <action> -- one with UPDATE one with DELETE

WHEN NOT MATCHED [BY TARGET] [AND <predicate>] -- one

--clause allowed:

THEN INSERT... –- if indicated, action must be INSERT

WHEN NOT MATCHED BY SOURCE [AND <predicate>] -- two

--clauses allowed:

THEN <action>; -- one with UPDATE one with DELETE

The following are the clauses of the statement and their roles:

**MERGE INTO <target table>** This clause defines the target table for

the operation. You can alias the table in this clause if you want.

**USING <source table>** This clause defines the source table for the

operation. You can alias the table in this clause if you want. Note that

the USING clause is designed similar to a FROM clause in a SELECT

query, meaning that in this clause you can define table operators like

joins, refer to a table expression like a derived table or a common table

expression (CTE), or even refer to a table function like

OPENROWSET. The outcome of the USING clause is eventually a

table result, and that table is considered the source of the merge

operation.

**ON <merge predicate>** In this clause, you specify a predicate that

matches rows between the source and the target and defines whether a

source row is or isn’t matched by a target row. Note that this clause

isn’t a filter like the ON clause in a join.

**WHEN MATCHED [AND <predicate>] THEN <action>** This

clause defines an action to take when a source row is matched by a

target row. Because a target row exists, an INSERT action isn’t allowed

in this clause. The two actions that are enabled are UPDATE and

DELETE. If you want to apply different actions in different conditions,

you can specify two WHEN MATCHED clauses, each with a different

additional predicate to determine when to apply an UPDATE and when

to apply a DELETE.

**WHEN NOT MATCHED [BY TARGET] [AND <predicate>]**

**THEN <action>**

This clause defines what action to take when a source row is not

matched by a target row. Because a target row does not exist, the only

action allowed in this clause (if you choose to include this clause in the

statement) is INSERT. Using UPDATE or DELETE holds no meaning

when a target row doesn’t exist. You can still add an additional

predicate that must be true in order to perform the action.

**WHEN NOT MATCHED BY SOURCE [AND <predicate>] THEN**

**<action>**

This clause is a proprietary extension by Microsoft to the standard

MERGE statement syntax. It defines an action to take when a target

row exists, but it is not matched by a source row. Because a target row

exists, you can apply either an UPDATE or a DELETE, but not an

INSERT. If you want, you can have two such clauses with different

additional predicates that define when to use an UPDATE and when to

use a DELETE.

To demonstrate examples of the MERGE statement, this section uses the

Sales.MyOrders table and the Sales.SeqOrderIDs sequence. Use the

following code to create these objects.

DROP TABLE IF EXISTS Sales.MyOrders;

DROP SEQUENCE IF EXISTS Sales.SeqOrderIDs;

CREATE SEQUENCE Sales.SeqOrderIDs AS INT

MINVALUE 1

CACHE 10000;

CREATE TABLE Sales.MyOrders

(

orderid INT NOT NULL

CONSTRAINT PK\_MyOrders\_orderid PRIMARY KEY

CONSTRAINT DFT\_MyOrders\_orderid

DEFAULT(NEXT VALUE FOR Sales.SeqOrderIDs),

custid INT NOT NULL

CONSTRAINT CHK\_MyOrders\_custid CHECK(custid > 0),

empid INT NOT NULL

CONSTRAINT CHK\_MyOrders\_empid CHECK(empid > 0),

orderdate DATE NOT NULL

);

Notice that the sequence is defined to start with the value 1, and uses a

cache size of 10,000 for performance reasons. The cache size defines how

frequently to write a recoverable value to disk. To request a new key from the

sequence, you use the function NEXT VALUE FOR <sequence\_name>. Our

code defines a default constraint with the function call for the orderid column

to automate the creation of keys when new rows are inserted.

Suppose that you need to define a stored procedure that accepts as input

parameters attributes of an order. If an order with the input order ID already

exists in the Sales.MyOrders table, you need to update the row, setting the

values of the nonkey columns to the new ones. If the order ID doesn’t exist in

the target table, you need to insert a new row. Because this book doesn’t

cover stored procedures until Chapter 3, the examples in this section use local

variables for now. A MERGE statement in a stored procedure simply refers

to the procedure’s input parameters instead of the local variables.

The first things to identify in a MERGE statement are the target and the

source tables. The target is easy—it’s the Sales.MyOrders table. The source

is supposed to be a table or table expression, but in this case, it’s just a set of

input parameters making an order. To turn the inputs into a table expression,

you can define a derived table based on the VALUES clause, which is also

known as a table value constructor. The following MERGE statement updates

the target row if the source key exists in the target, and inserts a new row if it

doesn’t:

DECLARE

@orderid AS INT = 1, @custid AS INT = 1,

@empid AS INT = 2, @orderdate AS DATE = '20170212';

MERGE INTO Sales.MyOrders WITH (SERIALIZABLE) AS TGT

USING (VALUES(@orderid, @custid, @empid, @orderdate))

AS SRC( orderid, custid, empid, orderdate)

ON SRC.orderid = TGT.orderid

WHEN MATCHED THEN

UPDATE

SET TGT.custid = SRC.custid,

TGT.empid = SRC.empid,

TGT.orderdate = SRC.orderdate

WHEN NOT MATCHED THEN

INSERT VALUES(SRC.orderid, SRC.custid, SRC.empid,

SRC.orderdate);

Observe that the MERGE predicate compares the source order ID with the

target order ID. When a match is found (the source order ID is matched by a

target order ID), the MERGE statement performs an UPDATE action that

updates the values of the nonkey columns in the target to those from the

respective source row.

When a match isn’t found (the source order ID is not matched by a target

order ID), the MERGE statement inserts a new row with the source order

information into the target.

### **Using the OUTPUT option**

T-SQL supports an OUTPUT clause for modification statements, which you

can use to return information from modified rows. You can use the output for

purposes like auditing, archiving and others.

I use the same Sales. MyOrders table and Sales.SeqOrderIDs sequence from the Merging data

section in my examples, so make sure you still have them around. Run the

following code to clear the table and reset the sequence start value to 1:

TRUNCATE TABLE Sales.MyOrders;

ALTER SEQUENCE Sales.SeqOrderIDs RESTART WITH 1;

The design of the OUTPUT clause is very similar to that of the SELECT

clause in the sense that you can specify expressions and assign them with

result column aliases. One difference from the SELECT clause is that, in the

OUTPUT clause, when you refer to columns from the modified rows, you

need to prefix the column names with the keywords *inserted* or *deleted*. Use

the prefix inserted when the rows are inserted rows and the prefix deleted

when they are deleted rows. In an UPDATE statement, inserted represents the

state of the rows after the update and deleted represents the state before the

update.

You can have the OUTPUT clause return a result set back to the caller

much like a SELECT does. Or you can add an INTO clause to direct the

output rows into a target table. In fact, you can have two OUTPUT clauses if

you like—the first with INTO directing the rows into a table, and the second

without INTO, returning a result set from the query. If you do use the INTO

clause, the target table cannot participate in either side of a foreign key

relationship and cannot have triggers defined on it.

**INSERT with OUTPUT**

The OUTPUT clause can be used in an INSERT statement to return

information from the inserted rows. An example for a practical use case is

when you have a multi-row INSERT statement that generates new keys by

using the identity property or a sequence, and you need to know which new

keys were generated.

For example, suppose that you need to query the Sales.Orders table and

insert orders shipped to Norway to the Sales.MyOrders table. You are not

going to use the original order IDs in the target rows; instead, let the

sequence object generate those for you. But you need to get back information

from the INSERT statement about which order IDs were generated, plus

additional columns from the inserted rows. To achieve this, simply add an

OUTPUT clause to the INSERT statement right before the query. List the

columns that you need to return from the inserted rows and prefix them with

the keyword inserted, as follows:

**Click here to view code image**

INSERT INTO Sales.MyOrders(custid, empid, orderdate)

OUTPUT

inserted.orderid, inserted.custid, inserted.empid,

inserted.orderdate

SELECT custid, empid, orderdate

FROM Sales.Orders

WHERE shipcountry = N'Norway';

## **Subqueries and table expressions**

### **Subqueries**

Subqueries can be self-contained—independent of the outer query; or they

can be correlated—namely, having a reference to a column from the table in

the outer query. In terms of the result of the subquery, it can be scalar, multivalued (table with a single column), or multi-column table-valued (table with multiple columns).

#### **Self-contained subqueries**

*Self-contained subqueries* are subqueries that have no dependency on the

outer query. If you want, you can highlight the inner query in SSMS and run

it independently. This makes the troubleshooting of problems with selfcontained subqueries easier compared to correlated subqueries.

As mentioned, a subquery can return different forms of results. It can

return a single value, table with multiple values in a single column, or even a

multi-column table result.

Subqueries that return a single value, or scalar subqueries, can be used

where a single-valued expression is expected, like in one side of a

comparison. For example, the following query uses a self-contained subquery

to return the products with the minimum unit price:

SELECT productid, productname, unitprice

FROM Production.Products

WHERE unitprice =

(SELECT MIN(unitprice)

FROM Production.Products);

As you can see, the subquery returns the minimum unit price from the

Production.Products table. The outer query then returns information about

products with the minimum unit price.

Note that if what’s supposed to be a scalar subquery returns in practice

more than one value, the code fails at run time. If the scalar subquery returns

an empty set, it is converted to a NULL.

A subquery can also return multiple values in the form of a single column

and multiple rows. Such a subquery can be used where a multi-valued result

is expected—for example, when using the IN predicate. As an example, the

following query uses a multi-valued subquery to return products supplied by

suppliers from Japan.

SELECT productid, productname, unitprice

FROM Production.Products

WHERE supplierid IN

(SELECT supplierid

FROM Production.Suppliers

WHERE country = N'Japan');

The inner query returns supplier IDs of suppliers from Japan. The outer

query then returns information about products whose supplier ID is in the set

returned by the subquery. As with predicates in general, you can negate an IN

predicate, so if you wanted to return products supplied by suppliers that are

not from Japan, simply change IN to NOT IN.

T-SQL supports a few esoteric predicates that operate on subqueries.

Those are ALL, ANY and SOME. They are rarely used because there are

usually simpler and more intuitive alternatives.

SELECT <select\_list>

FROM <table>

WHERE <expression> <operator> {ALL | ANY | SOME}

(<subquery>);

The ALL predicate returns true only if when applying the operator to the

input expression and all values returned by the subquery, you get a true in all

cases. For example, the following query is an alternative solution to the one

shown earlier for returning the product with the minimum unit price:

SELECT productid, productname, unitprice

FROM Production.Products

WHERE unitprice <= ALL

(SELECT unitprice FROM

Production.Products);

The way the query is phrased is “return the products where the unit price is

less than or equal to all product unit prices.”

The ANY and SOME predicates have identical meaning. Suffice that you

get a true for at least one of the values returned by the subquery for the whole

predicate to return true. As an example, the following query returns all

products with a unit price that is greater than the minimum.

SELECT productid, productname, unitprice

FROM Production.Products

WHERE unitprice > ANY

(SELECT unitprice FROM

Production.Products);

The way the query is phrased is “return the products where the unit price is

greater than any product unit prices.” This will be false only for the product

with the minimum price.

#### **Correlated subqueries**

*Correlated subqueries* are subqueries where the inner query has a reference

to a column from the table in the outer query. They are trickier to work with

compared to self-contained subqueries because you can’t just highlight the

inner portion and run it independently.

As an example, suppose that you need to return products with the

minimum unit price per category. You can use a correlated subquery to return

the minimum unit price out of the products where the category ID is equal to

the one in the outer row (the correlation), as follows:

SELECT categoryid, productid, productname, unitprice

FROM Production.Products AS P1

WHERE unitprice =

(SELECT MIN(unitprice)

FROM Production.Products AS P2

WHERE P2.categoryid = P1.categoryid);

Notice that the outer query and the inner query refer to different instances

of the same table, Production.Products. In order for the subquery to be able to

distinguish between the two, you must assign different aliases to the different

instances. The query assigns the alias P1 to the outer instance and P2 to the

inner instance, and by using the table alias as a prefix, you can refer to

columns in an unambiguous way. The subquery uses a correlation in the

predicate P2.categoryid = P1.categoryid, meaning that it filters

only the products where the category ID is equal to the one in the outer row.

So, when the outer row has category ID 1, the inner query returns the

minimum unit price out of all products where the category ID is 1. And when

the outer row has category ID 2, the inner query returns the minimum unit

price out of all the products where the category ID is 2; and so on.

As another example of a correlated subquery, the following query returns

customers who placed orders on February 12, 2016:

SELECT custid, companyname

FROM Sales.Customers AS C

WHERE EXISTS

( SELECT \*

FROM Sales.Orders AS O

WHERE O.custid = C.custid

AND O.orderdate = '20070212');

The EXISTS predicate accepts a subquery as input and returns true when

the subquery returns at least one row and false otherwise. In this case, the

subquery returns orders placed by the customer whose ID is equal to the

customer ID in the outer row (the correlation) and where the order date is

February 12, 2016. So the outer query returns a customer only if there’s at

least one order placed by that customer on the date in question.

As a predicate, EXISTS doesn’t need to return the result set of the

subquery; rather, it returns only true or false, depending on whether the

subquery returns any rows. For this reason, the query optimizer ignores the

SELECT list of the subquery, and therefore, whatever you specify there will

not affect optimization choices like index selection.

As with other predicates, you can negate the EXISTS predicate as well.

The following query negates the previous query’s predicate, returning

customers who did not place orders on February 12, 2016:

SELECT custid, companyname

FROM Sales.Customers AS C

WHERE NOT EXISTS

( SELECT \*

FROM Sales.Orders AS O

WHERE O.custid = C.custid

AND O.orderdate = '20160212');

**Optimization of subqueries versus joins**

When comparing the performance of solutions using subqueries versus

solutions using joins, you will find that it’s not like one tool always performs

better than the other.

I’ll start with an example where subqueries are optimized less efficiently

than joins. If you have multiple subqueries that need to apply computations

such as aggregates based on the same set of rows, SQL Server will perform a

separate access to the data for each subquery. With a join, you can apply

multiple aggregate calculations based on the same access to the data. For

example, suppose that you need to query the Sales.Orders table and compute

for each order the percent of the current freight value out of the customer

total, as well as the difference from the customer average. You create the

following covering index to support your solutions:

CREATE INDEX idx\_cid\_i\_frt\_oid

ON Sales.Orders(custid) INCLUDE(freight, orderid);

Here’s the solution for the task using correlated subqueries:

SELECT orderid, custid, freight,

freight / ( SELECT SUM(O2.freight)

FROM Sales.Orders AS O2

WHERE O2.custid = O1.custid ) AS pctcust,

freight - ( SELECT AVG(O3.freight)

FROM Sales.Orders AS O3

WHERE O3.custid = O1.custid ) AS diffavgcust

FROM Sales.Orders AS O1;

Here’s the solution for the task using a derived table and a join:

SELECT O.orderid, O.custid, O.freight,

freight / totalfreight AS pctcust,

freight - avgfreight AS diffavgcust

FROM Sales.Orders AS O

INNER JOIN ( SELECT custid, SUM(freight) AS

totalfreight, AVG(freight) AS avgfreight

FROM Sales.Orders

GROUP BY custid ) AS A

ON O.custid = A.custid;

In the second example, consider a case where SQL Server optimizes

subqueries better than joins. For this example, first run the following code to

add a shipper row into the Sales.Shippers table:

INSERT INTO Sales.Shippers(companyname, phone)

VALUES('Shipper XYZ', '(123) 456-7890');

Your task is to write a solution that returns shippers who didn’t handle any

orders yet. The important index for this task is a nonclustered index on the

shipperid column in the Sales.Orders table, which already exists.

Here’s a solution to the task based on a subquery.

SELECT S.shipperid

FROM Sales.Shippers AS S

WHERE NOT EXISTS

( SELECT \*

FROM Sales.Orders AS O

WHERE O.shipperid = S.shipperid);

Here’s a solution to the task based on a join:

SELECT S.shipperid

FROM Sales.Shippers AS S

LEFT OUTER JOIN Sales.Orders AS O

ON S.shipperid = O.shipperid

WHERE O.orderid IS NULL;

### **The APPLY operator**

The APPLY operator is a powerful operator that you can use to apply some

query logic to each row from a table. The operator evaluates the left input

first, and for each of its rows, applies a derived table query or table function

that you provide as the right input. What’s interesting

about the APPLY operator as compared to a join is that a join treats its two

inputs as a set of inputs, and recall that a set has no order. This means that if

any of the join inputs is a query, you cannot refer in that query to elements

from the other side. In other words—correlations aren’t allowed. Conversely,

the APPLY operator evaluates the left side first, and for each of the left rows,

applies the table expression that you provide as the right input. As a result,

the query in the right side can have references to elements from the left side.

If this sounds similar to a correlated subquery, that’s for a good reason. The

references from the right side to elements from the left are correlations.

However, with normal subqueries you’re generally limited to returning only

one column, whereas with an applied table expression you can return a whole

table result with multiple columns and multiple rows. This means that you

can replace the use of cursors in some cases with the APPLY operator.

For example, suppose that you have a query that performs some logic for a

particular supplier. And let’s also suppose that you need to apply this query

logic to each supplier from the Production.Suppliers table. You could use a

cursor to iterate through the suppliers, and in each iteration invoke the query

for the current supplier. Instead, you can use the APPLY operator, providing

the Production.Suppliers table as the left input, and a table expression based

on your query as the right input. You can correlate the supplier ID in the

inner query of the right table expression to the supplier ID from the left table.

The two forms of the APPLY operator—CROSS and OUTER—are

described in the next sections.

#### **CROSS APPLY**

The CROSS APPLY operator operates on left and right inputs. The right

table expression can have a correlation to elements from the left table. The

right table expression is applied to each row from the left input. What’s

special about the CROSS APPLY operator as compared to OUTER APPLY

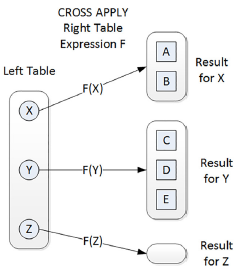
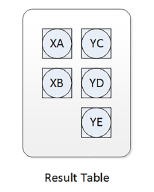
is that if the right table expression returns an empty set for a left row, the left

row isn’t returned. The reason that this operator is called *CROSS* APPLY is

that per the left row, the operator behaves like a cross join between that row

and the result set returned for it from the right input. Figure 2-3 shows an

illustration of the CROSS APPLY operator.

The letters X, Y, and Z represent key values from the left table. F

represents the table expression provided as the right input, and in parentheses,

you can see the key value from the left row passed as the correlated element.

On the right side of the illustration, you can see the result returned from the

right table expression for each left row. Then at the bottom, you can see the

result of the CROSS APPLY operator, where left rows are matched with the

respective right rows that were returned for them. Notice that a left row that

gets an empty set back from the right table expression isn’t returned. That’s

just like with a cross join between one row and zero rows; the result is an

empty set. Such is the case with the row with the key value Z.

As an example, consider the following query, which returns the two

products with the lowest unit prices for supplier 1:

SELECT TOP (2) productid, productname, unitprice

FROM Production.Products

WHERE supplierid = 1

ORDER BY unitprice, productid;

Suppose that you need to apply this logic to each of the suppliers from

Japan that you have in the Production.Suppliers table. You don’t want to use

a cursor to iterate through the suppliers one at a time and invoke a separate

query for each. Instead, you can use the CROSS APPLY operator, like so:

SELECT S.supplierid, S.companyname AS supplier, A.\*

FROM Production.Suppliers AS S

CROSS APPLY (SELECT TOP (2) productid, productname,

unitprice

FROM Production.Products AS P

WHERE P.supplierid = S.supplierid

ORDER BY unitprice, productid) AS A

WHERE S.country = N'Japan';

As you can see in the query, the left input to the APPLY operator is the

Production.Suppliers table, with only suppliers from Japan filtered. The right

table expression is a correlated derived table returning the two products with

the lowest prices for the left supplier. Because the APPLY operator applies

the right table expression to each supplier from the left, you get the two

products with the lowest prices for each supplier from Japan. Because the

CROSS APPLY operator doesn’t return left rows for which the right table

expression returns an empty set, suppliers from Japan who don’t have any

related products aren’t returned.

#### **OUTER APPLY**

The OUTER APPLY operator extends what the CROSS APPLY operator

does by also including in the result rows from the left side that get an empty

set back from the right side. NULLs are used as placeholders for the result

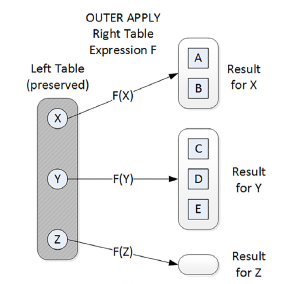
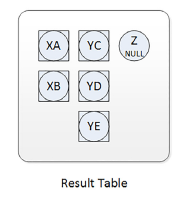
columns from the right side. In other words, the OUTER APPLY operator

preserves the left side. In a sense, for each single left row, the difference

between OUTER APPLY and CROSS APPLY is similar to the difference

between a LEFT OUTER JOIN and a CROSS JOIN. Figure 2-4 shows an

illustration of the OUTER APPLY operator:

Observe that this time the left row with the key value Z is preserved.

Let’s re-examine the example returning the two products with the lowest

prices per supplier from Japan: If you use the OUTER APPLY operator

instead of CROSS APPLY, you will preserve the left side. Here’s the revised

query.

SELECT S.supplierid, S.companyname AS supplier, A.\*

FROM Production.Suppliers AS S

OUTER APPLY (SELECT TOP (2) productid, productname,

unitprice

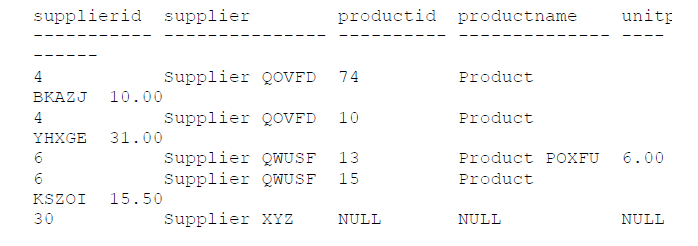
FROM Production.Products AS P

WHERE P.supplierid = S.supplierid

ORDER BY unitprice, productid) AS A

WHERE S.country = N'Japan';

Here’s the output of this query.



### **Query data by using table expressions**

**Table expressions, described**

Table expressions are named queries. You write an inner query that returns a

relational result set, name it, and query it from an outer query. T-SQL

supports four forms of table expressions: derived tables, common table

expressions (CTEs), views and inline table-valued functions.

The first two forms are visible only to the statement that defines them. As

for the last two forms, you preserve the definition of the table expression in

the database as an object; therefore, it’s reusable, and you can also control

access to the object with permissions.

Note that because a table expression is supposed to represent a relation, the

inner query defining it needs to be relational. This means that all columns

returned by the inner query must have names (use aliases if the column is a

result of an expression), and all column names must be unique. Also, the

inner query is not allowed to have an ORDER BY clause. (Remember, a set

has no order.) There’s an exception to the last rule: If you use the TOP or

OFFSET-FETCH option in the inner query, the ORDER BY serves a

meaning that is not related to presentation ordering; rather, it’s part of the

filter’s specification. So if the inner query uses the TOP or OFFSET-FETCH

option, it’s allowed to have an ORDER BY clause as well. But then the outer

query has no presentation ordering guarantees if it doesn’t have its own

ORDER BY clause.

**Table expressions or temporary tables?**

It’s important to note that, from a performance standpoint, when SQL Server

optimizes queries involving table expressions, it first unnests, or inlines, the

table expression’s logic, and therefore interacts with the underlying tables

directly. It does not somehow persist the table expression’s result in an

internal work table and then interact with that work table. If for optimization

reasons you do need to persist the result of a query for further processing, you

should be using a temporary table or table variable.

There are cases where the use of table expressions is more optimal than

temporary tables. For instance, imagine that you need to query some table T1

only once, then interact with the result of that query from some outer query,

and finally interact with the result of that outer query from yet another outer

query. You do not want to pay the penalty of writing the intermediate results

physically to some temporary table, rather, you want the physical processing

to interact directly with the underlying table. To achieve this, define a table

expression based on the query against T1, give it a name, say D1, and then

write an outer query against D1. Behind the scenes, SQL Server will unnest,

or inline, the logic of the inner queries, like pealing the layers of an onion,

and the query plan will interact directly with T1.

There are cases where you will get more optimal treatment when using

temporary tables (which you create like regular tables, and name with a #

sign as a prefix, such as #T1) or table variables (which you declare, and name

with the @ sign as a prefix, such as @T1). That’s typically the case when you

have some expensive query, like one that scans large tables, joins them, and

groups and aggregates the data. You need to interact with that query result

multiple times—whether with a single query that joins multiple instances of

the result or with multiple separate queries. If you use a table expression, the

physical treatment repeats the work for each reference. In such cases you

want to persist the result of the expensive work in a temporary table or table

variable, and then interact with that temporary object a number of times.

Between table variables and temporary tables, the main difference from an

optimization perspective is that SQL Server maintains full blown statistics on

temporary tables but very minimal statistics on table variables. Therefore,

cardinality estimates (estimates for row counts during optimization) tend to

be more accurate with temporary tables. So, when dealing with very small

amounts of data like just a few rows, typically it’s recommended to use table

variables since that’s the assumption that the optimizer makes any way. With

larger table sizes, the recommendation is to use temporary tables, to allow

better estimates, that will hopefully result in more optimal plans.

#### **Derived tables**

A derived table is a named table subquery. You define the derived table’s

inner query in parentheses in the FROM clause of the outer query, and

specify the name of the derived table after the parentheses.

Before demonstrating the use of derived tables, this section describes a

query that returns a certain desired result. Then it explains a need that cannot

be addressed directly in the query, and shows how you can address that need

by using a derived table (or any other table expression type for that matter).

Consider the following query, which computes row numbers for products,

partitioned by categoryid, and ordered by unitprice and

productid:

SELECT

ROW\_NUMBER()

OVER

(

PARTITION BY categoryid

ORDER BY

unitprice,

productid

) AS rownum,

categoryid, productid, productname, unitprice

FROM Production.Products;

**Introduction to SQL Server ROW\_NUMBER() function**

The ROW\_NUMBER() is a [window function](https://www.sqlservertutorial.net/sql-server-window-functions/) that assigns a sequential integer to each row within the partition of a result set. The row number starts with 1 for the first row in each partition.

The following shows the syntax of the ROW\_NUMBER() function:

ROW\_NUMBER() OVER (

[PARTITION BY partition\_expression, ... ]

ORDER BY sort\_expression [ASC | DESC], ...

)

Let’s examine the syntax of the ROW\_NUMBER() function in detail.

**PARTITION BY**

The PARTITION BY clause divides the result set into partitions (another term for groups of rows). The ROW\_NUMBER() function is applied to each partition separately and reinitialized the row number for each partition.

The PARTITION BY clause is optional. If you skip it, the ROW\_NUMBER() function will treat the whole result set as a single partition.

**ORDER BY**

The ORDER BY clause defines the logical order of the rows within each partition of the result set. The ORDER BY clause is mandatory because the ROW\_NUMBER() function is order sensitive.

The ROW\_NUMBER function computes unique incrementing integers from 1 and is based on indicated ordering, possibly within partitions of rows. As you can see in the query’s result, the ROW\_NUMBER function generates unique incrementing integers starting with 1 based on unitprice and productid ordering, within each partition defined by categoryid.

The thing with the ROW\_NUMBER function—and window functions in

general—is that they are only allowed in the SELECT and ORDER BY

clauses of a query. So, what if you want to filter rows based on such a

function’s result? For example, suppose you want to return only the rows

where the row number is less than or equal to 2; namely, in each category

you want to return the two products with the lowest unit prices, with the

product ID used as a tiebreaker. You are not allowed to refer to the

ROW\_NUMBER function in the query’s WHERE clause. Remember also

that according to logical query processing, you’re not allowed to refer to a

column alias that was assigned in the SELECT list in the WHERE clause,

because the WHERE clause is conceptually evaluated before the SELECT

clause.

You can circumvent the restriction by using a table expression. You write a

query such as the previous query that computes the window function in the

SELECT clause, and assign a column alias to the result column. You then

define a table expression based on that query, and refer to the column alias in

the outer query’s WHERE clause, like so:

SELECT categoryid, productid, productname, unitprice

FROM (SELECT

ROW\_NUMBER() OVER(PARTITION BY categoryid

ORDER BY unitprice, productid)

AS rownum,

categoryid, productid, productname, unitprice

FROM Production.Products) AS D

WHERE rownum <= 2;

As you can see, the derived table is defined in the FROM clause of the

outer query in parentheses, followed by the derived table name. Then the

outer query is allowed to refer to column aliases that were assigned by the

inner query. That’s a classic use of table expressions.

Two column aliasing options are available to you when working with

derived tables: both inline and external. With the inline form, you specify the

column alias as part of the expression, as in <expression> AS alias. The last

query used the inline form to assign the alias rownum to the expression with

the ROW\_NUMBER function. With the external aliasing form, you don’t

specify result column aliases as part of the column expressions; instead, you

name all target columns right after the derived table’s name, as in FROM (…)

AS D(rownum, categoryid, productid, productname,

unitprice). With the external form, you must specify all target column

names and not just those that are results of computations. If you use both

inline and external aliases, the external ones prevail as far as the outer query

is concerned.

There are a couple of problematic aspects to working with derived tables

that stem from the fact that a derived table is defined in the FROM clause of

the outer query. One problem has to do with cases where you want to refer to

one derived table from another. In such a case, you end up nesting derived

tables, and nesting often complicates the logic, making it hard to follow and

increasing the likelihood for errors. Consider the following general form of

nesting of derived tables:

SELECT ...

FROM ( SELECT

FROM (SELECT ...

FROM T1

WHERE ...) AS D1

WHERE ...) AS D2

WHERE ...;

The other problem with derived tables has to do with the fact that a join

treats its two inputs as a set, meaning no order; the two inputs are evaluated

in an *all-at-once* manner. As a result, if you define a derived table as the left

input of the join, that derived table is not visible to the right input of the join.

This means that if you want to join multiple instances of the same derived

table, you can’t. You have no choice but to duplicate the code, defining

multiple derived tables based on the same query. The general form of such a

query looks like this:

SELECT ...

FROM ( SELECT ...

FROM T1) AS D1

INNER JOIN

( SELECT ...

FROM T1) AS D2

ON ...;

The derived tables D1 and D2 are based on the same query. This repetition

of code increases the likelihood for errors when you need to make revisions

to the inner queries.

#### **Common table expressions**

A common table expression (CTE) is a similar concept to a derived table in

the sense that it’s a named table expression that is visible only to the

statement that defines it. Like a query against a derived table, a query against

a CTE involves three main parts:

* The inner query
* The name you assign to the query and its columns
* The outer query

However, with CTEs, the arrangement of the three parts is different. Recall

that with derived tables the inner query appears in the FROM clause of the

outer query—in the middle of things. With CTEs, you first name the CTE,

then specify the inner query, and then the outer query—a much more modular

approach:

WITH <CTE\_name>

AS

(

<inner\_query>

)

<outer\_query>;

Recall the example from the section about derived tables where you

returned for each product category the two products with the lowest unit

prices. Here’s how you can implement the same task with a CTE:

WITH C AS

(

SELECT

ROW\_NUMBER() OVER(

PARTITION BY categoryid

ORDER BY unitprice, productid) AS

rownum,

categoryid, productid, productname, unitprice

FROM Production.Products

)

SELECT categoryid, productid, productname, unitprice

FROM C

WHERE rownum <= 2;

As you can see, it’s a similar concept to derived tables, except the inner

query is not defined in the middle of the outer query. Instead, first you name

the table expression, then define the inner query—from start to end and then

the outer query—from start to end. This design leads to much clearer code

that is easier to understand.

You don’t nest CTEs like you do derived tables. If you need to define

multiple CTEs, you simply separate them by commas. Each can refer to the

previously defined CTEs, and the outer query can refer to all of them. After

the outer query terminates, all CTEs defined in that WITH statement are

gone. The fact that you don’t nest CTEs makes it easier to follow the logic

and therefore reduces the chances for errors. For example, if you want to

refer to one CTE from another, you can use the following general form:

WITH C1 AS

(

SELECT ...

FROM T1

WHERE ...

),

C2 AS

(

SELECT

FROM C1

WHERE ...

)

SELECT ...

FROM C2

WHERE ...;

Because the CTE name is assigned before the start of the outer query, you

can refer to multiple instances of the same CTE name, unlike with derived

tables. The general form looks like the following.

WITH C AS

(

SELECT ...

FROM T1

)

SELECT ...

FROM C AS C1

INNER JOIN C AS C2

ON ...;

#### **Views and inline table-valued functions**

Derived tables and CTEs are table expressions that are visible only in the scope of the statement that defines them. After that statement terminates, the table expression is gone. Hence, derived tables and CTEs are not reusable. For reusability, you need to store the definition of the table expression as an object in the database, and for this you can use either views or inline table-valued functions. Because these are objects in the database, you can control access by assigning permissions.

The main difference between views and inline table-valued functions is

that the former doesn’t accept input parameters and the latter does. As an

example, suppose you need to persist the definition of the query with the row

number computation from the examples in the previous sections. To achieve

this, you create the following view:

DROP VIEW IF EXISTS Sales.RankedProducts;

GO

CREATE VIEW Sales.RankedProducts

AS

SELECT

ROW\_NUMBER()

OVER(PARTITION BY categoryid

ORDER BY unitprice, productid) AS

rownum,

categoryid, productid, productname, unitprice

FROM Production.Products;

GO

Note that it’s not the result set of the view that is stored in the database;

rather, only its definition is stored. Now that the definition is stored, the

object is reusable. Whenever you need to query the view, it’s available to

you, assuming you have the permissions to query it:

SELECT categoryid, productid, productname, unitprice

FROM Sales.RankedProducts

WHERE rownum <= 2;

As for inline table-valued functions, they are very similar to views in

concept; however, as mentioned, they do support input parameters. So if you

want to define something like a view with parameters, the closest you have is

an inline table-valued function. As an example, consider the recursive CTE

from the section about CTEs that retuned the management chain leading all

the way up to the CEO for a specified employee. Suppose that you wanted to

encapsulate the logic in a table expression for reusability, but also wanted to

parameterize the input employee instead of using the constant 9. You can

achieve this by using an inline table-valued function with the following

definition:

DROP FUNCTION IF EXISTS HR.GetManagers;

GO

CREATE FUNCTION HR.GetManagers(@empid AS INT) RETURNS

TABLE

AS

RETURN

WITH EmpsCTE AS

(

SELECT empid, mgrid, firstname, lastname, 0 AS

distance

FROM HR.Employees

WHERE empid = @empid

UNION ALL

SELECT M.empid, M.mgrid, M.firstname, M.lastname,

S.distance + 1 AS distance

FROM EmpsCTE AS S

JOIN HR.Employees AS M

ON S.mgrid = M.empid

)

SELECT empid, mgrid, firstname, lastname, distance

FROM EmpsCTE;

GO

## **Group and pivot data by using queries**

**Writing grouped queries**

You can use grouped queries to define groups in your data, and then you can

perform data analysis computations per group. You group the data by a set of

expressions known as a grouping set. Traditional T-SQL queries define a

single grouping set; namely, they group the data in only one way. T-SQL also

supports defining multiple grouping sets in one query.

### **Working with a single grouping set**

With grouped queries, you can arrange the rows you’re querying in groups

and apply data analysis computations like aggregate functions against those

groups. A query becomes a grouped query when you use a group function, a

GROUP BY clause, or both.

A query that invokes a group aggregate function but doesn’t have an

explicit GROUP BY clause arranges all rows in one group. Such an

aggregate is referred to as a *scalar aggregate*. Consider the following query

as an example:

USE TSQLV4;

SELECT COUNT(\*) AS numorders

FROM Sales.Orders;

This query generates the following output.

numorders

-----------

830

Because there’s no explicit GROUP BY clause, all rows queried from the

Sales.Orders table are arranged in one group, and then the COUNT(\*)

function counts the number of rows in that group. Grouped queries return one

result row per group, and because the query defines only one group, it returns

only one row in the result set.

Using an explicit GROUP BY clause, you can group the rows based on a

specified grouping set of expressions. For example, the following query

groups the rows by shipper ID and counts the number of rows (orders, in this

case) per distinct group:

SELECT shipperid, COUNT(\*) AS numorders

FROM Sales.Orders

GROUP BY shipperid;

This query generates the following output:

shipperid numorders

----------- -----------

1 249

2 326

3 255

The query identifies three groups because there are three distinct shipper

IDs.

The grouping set can be made of multiple elements. For example, the

following query groups the rows by shipper ID and shipped year:

SELECT shipperid, YEAR(shippeddate) AS shippedyear,

COUNT(\*) AS numorders

FROM Sales.Orders

GROUP BY shipperid, YEAR(shippeddate);

This query generates the following output:

|  |  |  |
| --- | --- | --- |
| shipperid | shippedyear | numorders |
| 1 | 2014 | 36 |
| 2 | 2015 | 143 |
| 1 | NULL | 4 |
| 3 | 2016 | 73 |
| 3 | NULL | 6 |
| 3 | 2014 | 51 |
| 2 | 2016 | 116 |
| 2 | NULL | 11 |
| 1 | 2015 | 130 |
| 3 | 2015 | 125 |
| 1 | 2016 | 79 |
| 2 | 2014 | 56 |

Notice that you get a group for each distinct shipper ID and shipped year

combination that exists in the data, even when the shipped year is NULL.

Remember that a NULL in the shippeddate column represents unshipped orders, so a NULL in the shippedyear column represents the group of unshipped orders for the respective shipper.

If you need to filter entire groups, you need a filtering option that is

evaluated at the group level—unlike the WHERE clause, which is evaluated

at the row level. For this, T-SQL provides the HAVING clause. Like the

WHERE clause, the HAVING clause uses a predicate but evaluates the

predicate per group as opposed to per row. This means that you can refer to

aggregate computations because the data has already been grouped.

For example, suppose that you need to group only shipped orders by

shipper ID and shipping year, and filter only groups having fewer than 100

orders. You can use the following query to achieve this task:

SELECT shipperid, YEAR(shippeddate) AS shippedyear,

COUNT(\*) AS numorders

FROM Sales.Orders

WHERE shippeddate IS NOT NULL

GROUP BY shipperid, YEAR(shippeddate)

HAVING COUNT(\*) < 100;

This query generates the following output.

shipperid shippedyear numorders

----------- ----------- -----------

1 2014 36

3 2016 73

3 2014 51

1 2016 79

2 2014 56

Notice that the query filters only shipped orders in the WHERE clause.

This filter is applied at the row level conceptually before the data is grouped.

Next the query groups the data by shipper ID and shipped year. Then the

HAVING clause filters only groups that have a count of rows (orders) that is

less than 100. Finally, the SELECT clause returns the shipper ID, shipped

year, and count of orders per remaining group.

T-SQL supports a number of aggregate functions. Those include

COUNT(\*) and a few general set functions (as they are categorized by

standard SQL) like COUNT, SUM, AVG, MIN, and MAX. General set

functions are applied to an expression and ignore NULLs.

The following query invokes the COUNT(\*) function, in addition to a

number of general set functions, including COUNT:

SELECT shipperid,

COUNT(\*) AS numorders,

COUNT(shippeddate) AS shippedorders,

MIN(shippeddate) AS firstshipdate,

MAX(shippeddate) AS lastshipdate,

SUM(val) AS totalvalue

FROM Sales.OrderValues

GROUP BY shipperid;

This query generates the following output:

shipperid numorders shippedorders fshipdate lshipdate total

3 255 249 2014-07-15 2016-05-01 383405.53

1 249 245 2014-07-10 2016-05-04 348840.00

2 326 315 2014-07-11 2016-05-06 533547.69

Notice the difference between the results of COUNT(shippeddate) and

COUNT(\*). The former ignores NULLs in the shippeddate column, and

therefore the counts are less than or equal to those produced by the latter.

With aggregate functions, you can work with distinct occurrences by

specifying a DISTINCT clause before the expression, as follows:

SELECT shipperid, COUNT(DISTINCT shippeddate) AS

numshippingdates

FROM Sales.Orders

GROUP BY shipperid;

This query generates the following output.

shipperid numshippingdates

----------- -----------------

1 188

2 215

3 198

Note that the DISTINCT option is available not only to the COUNT

function, but also to other general set functions. However, it’s more common

to use it with COUNT.

From a logical query processing perspective, the GROUP BY clause is

evaluated after the FROM and WHERE clauses, and before the HAVING,

SELECT, and ORDER BY clauses. So the last three clauses already work

with a grouped table, and therefore the expressions that they support are

limited. Each group is represented by only one result row; therefore, all

expressions that appear in those clauses must guarantee a single result value

per group. There’s no problem referring directly to elements that appear in

the GROUP BY clause because each of those returns only one distinct value

per group. But if you want to refer to elements from the underlying tables that

don’t appear in the GROUP BY list, you must apply an aggregate function to

them. That’s how you can be sure that the expression returns only one value

per group. As an example, the following query isn’t valid:

SELECT S.shipperid, S.companyname, COUNT(\*) AS numorders

FROM Sales.Shippers AS S

INNER JOIN Sales.Orders AS O

ON S.shipperid = O.shipperid

GROUP BY S.shipperid;

This query generates the following error:

Msg 8120, Level 16, State 1, Line 58

Column 'Sales.Shippers.companyname' is invalid in the

select list because it is not

contained in either an aggregate function or the GROUP BY

clause.

Even though you know that there can’t be more than one distinct company

name per distinct shipper ID, T-SQL doesn’t know this. Because the

S.companyname column neither appears in the GROUP BY list nor is it

contained in an aggregate function, it’s not allowed in the HAVING,

SELECT, and ORDER BY clauses.

You can use a number of workarounds. One solution is to add the

S.companyname column to the GROUP BY list, as follows:

SELECT S.shipperid, S.companyname,

COUNT(\*) AS numorders

FROM Sales.Shippers AS S

INNER JOIN Sales.Orders AS O

ON S.shipperid = O.shipperid

GROUP BY S.shipperid, S.companyname;

Another workaround is to apply an aggregate function like MAX to the

column, as follows:

SELECT S.shipperid,

MAX(S.companyname) AS companyname,

COUNT(\*) AS numorders

FROM Sales.Shippers AS S

INNER JOIN Sales.Orders AS O

ON S.shipperid = O.shipperid

GROUP BY S.shipperid;

In this case, the aggregate function is an artificial one because there can’t

be more than one distinct company name per distinct shipper ID. The first

workaround, though, tends to produce more optimal plans, and also seems to

be the more natural solution.

The third workaround is to group and aggregate the rows from the Orders

table first, define a table expression based on the grouped query, and then

join the table expression with the Shippers table to get the shipper company

names. Here’s the solution’s code:

WITH C AS

(

SELECT shipperid, COUNT(\*) AS numorders

FROM Sales.Orders

GROUP BY shipperid

)

SELECT S.shipperid, S.companyname, numorders

FROM Sales.Shippers AS S

INNER JOIN C

ON S.shipperid = C.shipperid;

SQL Server usually optimizes the third solution like it does the first. The

first solution might be preferable because it involves much less code.

### **Working with multiple grouping sets**

With T-SQL, you can define multiple grouping sets in the same query. In

other words, you can use one query to group the data in more than one way.

T-SQL supports three clauses that allow defined multiple grouping sets:

GROUPING SETS, CUBE, and ROLLUP. You use these in the GROUP BY

clause.

#### **GROUPING SETS**

You can use the GROUPING SETS clause to list all grouping sets that you

want to define in the query. As an example, the following query defines four

grouping sets:

SELECT shipperid, YEAR(shippeddate) AS shipyear, COUNT(\*)

AS numorders

FROM Sales.Orders

WHERE shippeddate IS NOT NULL -- exclude unshipped orders

GROUP BY GROUPING SETS

(

( shipperid, YEAR(shippeddate) ),

( shipperid ),

( YEAR(shippeddate) ),

( )

);

You list the grouping sets separated by commas within the outer pair of

parentheses, which belongs to the GROUPING SETS clause. You use an

inner pair of parentheses to enclose each grouping set. If you don’t indicate

an inner pair of parentheses, each individual element is considered a separate

grouping set.

This query defines four grouping sets. One of them is the empty grouping

set, which defines one group with all rows for computation of grand

aggregates. The query generates the following output:

|  |  |  |
| --- | --- | --- |
| shipperid | shipyear | numorders |
| 1 | 2014 | 36 |
| 2 | 2014 | 56 |
| 3 | 2014 | 51 |
| NULL | 2014 | 143 |
| 1 | 2015 | 130 |
| 2 | 2015 | 143 |
| 3 | 2015 | 125 |
| NULL | 2015 | 398 |
| 1 | 2016 | 79 |
| 2 | 2016 | 116 |
| 3 | 2016 | 73 |
| NULL | 2016 | 268 |
| NULL | NULL | 809 |
| 3 | NULL | 249 |
| 1 | NULL | 245 |
| 2 | NULL | 315 |

The output combines the results of grouping and aggregating the data of

four different grouping sets. As you can see in the output, NULLs are used as

placeholders in rows where an element isn’t part of the grouping set. For

example, in result rows that are associated with the grouping set (shipperid),

the shipyear result column is set to NULL. Similarly, in rows that are

associated with the grouping set (YEAR(shippeddate)), the shipperid

column is set to NULL.

You can achieve the same result by writing four separate grouped queries

—each defining only a single grouping set—and unifying their results with a

UNION ALL operator. However, such a solution would involve much more

code and won’t get optimized as efficiently as the query with the

GROUPING SETS clause.

#### **CUBE**

T-SQL supports two additional clauses called CUBE and ROLLUP, which

you can consider as abbreviations of the GROUPING SETS clause. The

CUBE clause accepts a list of expressions as inputs and defines all possible

grouping sets that can be generated from the inputs—including the empty

grouping set. For example, the following query is a logical equivalent of the

previous query that used the GROUPING SETS clause:

SELECT shipperid, YEAR(shippeddate) AS shipyear, COUNT(\*)

AS numorders

FROM Sales.Orders

WHERE shippeddate IS NOT NULL

GROUP BY CUBE( shipperid, YEAR(shippeddate) );

The CUBE clause defines all four possible grouping sets from the two

inputs:

1. ( shipperid, YEAR(shippeddate) )
2. ( shipperid )
3. ( YEAR(shippeddate) )
4. ( )

#### **ROLLUP**

The ROLLUP clause is also an abbreviation of the GROUPING SETS

clause, but you use it when there’s a natural hierarchy formed by the input

elements. In such a case, only a subset of the possible grouping sets is really

interesting. Consider, for example, a location hierarchy made of the elements

shipcountry, shipregion, and shipcity, in this order. It’s only

interesting to roll up the data in one direction, computing aggregates for the

following grouping sets:

* ( shipcountry, shipregion, shipcity )
* ( shipcountry, shipregion )
* ( shipcountry )
* ( )

The other grouping sets are simply not interesting. For example, even

though the same city name can appear in different places in the world, it’s not

interesting to aggregate all of the occurrences—irrespective of region and

country.

So, when the elements form a hierarchy, you use the ROLLUP clause and

this way avoid computing unnecessary aggregates. Here’s an example of a

query using the ROLLUP clause based on the aforementioned hierarchy:

SELECT shipcountry, shipregion, shipcity, COUNT(\*) AS

numorders

FROM Sales.Orders

GROUP BY ROLLUP( shipcountry, shipregion, shipcity );

### **Pivoting and Unpivoting Data**

Pivoting is a specialized case of grouping and aggregating of data.

Unpivoting is, in a sense, the inverse of pivoting. T-SQL supports native

operators for both. Let’s first describe the PIVOT operator and then the

UNPIVOT operator.

**Pivoting Data**

Pivoting is a technique that groups and aggregates data, transitioning it from

a state of rows to a state of columns. In all pivot queries, you need to identify

three elements:

**1.** What do you want to see on rows? This element is known as the *on*

*rows*, or *grouping* element.

**2.** What do you want to see on columns? This element is known as the *on*

*cols*, or *spreading* element.

**3.** What do you want to see in the intersection of each distinct row and

column value? This element is known as the *data*, or *aggregation*

element.

As an example of a pivot request, suppose that you want to query the

Sales.Orders table. You want to return a row for each distinct customer ID

(the grouping element), a column for each distinct shipper ID (the spreading

element), and in the intersection of each customer and shipper you want to

see the sum of freight values (the aggregation element). With T-SQL, you can

achieve such a pivoting task by using the PIVOT table operator. The

recommended form for a pivot query (more on why it’s the recommended

form later) is generally like the following.

WITH PivotData AS

(

SELECT

< grouping column >,

< spreading column >,

< aggregation column >

FROM < source table >

) SELECT <select list >

FROM PivotData

PIVOT( < aggregate function >(< aggregation column >)

FOR < spreading column > IN (< distinct spreading

values >) ) AS P;

This recommended general form is made of the following elements:

* You define a table expression (like the one named PivotData) that

returns the three elements that are involved in pivoting, which in this

example are custid, shipperid and freight from Sales.Orders.

It is not recommended to query the underlying source table directly; the

reason for this is explained shortly.

* You issue the outer query against the table expression and apply the

PIVOT operator to that table expression. The PIVOT operator returns a

table result. You need to assign an alias to that table, for example, P.

* The specification for the PIVOT operator starts by indicating an

aggregate function applied to the aggregation element—in this

example, SUM(freight).

* Then you specify the FOR clause followed by the spreading column,

which in this example is shipperid.

* Then you specify the IN clause followed by the list of distinct values

that appear in the spreading element, separated by commas. What used

to be values in the spreading column (in this example, shipper IDs)

become column names in the result table. Therefore, the items in the list

should be expressed as column identifiers. Remember that if a column

identifier is irregular, it has to be delimited. Because shipper IDs are

integers, they have to be delimited: [1],[2],[3].

Following this recommended syntax for pivot queries, the following query

addresses our task (return customer IDs on rows, shipper IDs on columns,

and the total freight in the intersections):

WITH PivotData AS

(

SELECT

custid, -- grouping column

shipperid, -- spreading column

freight -- aggregation column

FROM Sales.Orders

) SELECT custid, [1], [2], [3]

FROM PivotData

PIVOT(SUM(freight) FOR shipperid IN ([1],[2],[3]) ) AS

P;

If you look carefully at the specification of the PIVOT operator, you will

notice that you indicate the aggregation and spreading elements, but not the

grouping element. The grouping element is identified by elimination—it’s

what’s left from the queried table besides the aggregation and spreading

elements. This is why it is recommended to prepare a table expression for the

pivot operator returning only the three elements that should be involved in

the pivoting task. If you query the underlying table directly (Sales.Orders in

this case), all columns from the table besides the aggregation (freight) and

spreading (shipperid) columns will implicitly become your grouping

elements. This includes even the primary key column orderid. So instead of

getting a row per customer, you end up getting a row per order. You can see

it for yourself by running the following code:

SELECT custid, [1], [2], [3]

FROM Sales.Orders

PIVOT(SUM(freight) FOR shipperid IN ([1],[2],

[3]) ) AS P;

You get 830 rows back because there are 830 rows in the Sales.Orders

table. By defining a table expression as was shown in the recommended

solution, you control which columns will be used as the grouping columns. If

you return custid, shipperid, and freight in the table expression,

and use the last two as the spreading and aggregation elements, respectively,

the PIVOT operator implicitly assumes that custid is the grouping

element. Therefore, it groups the data by custid, and as a result, returns a

single row per customer.

#### **Limitations of the PIVOT operator**

You should be aware of a few limitations of the PIVOT operator.

* The aggregation and spreading elements cannot directly be results of

expressions; instead, they must be column names from the queried

table. You can, however, apply expressions in the query defining the

table expression, assign aliases to those expressions, and then use the

aliases in the PIVOT operator.

* The COUNT(\*) function isn’t allowed as the aggregate function used

by the PIVOT operator. If you need a count, you have to use the

general COUNT(<col name>) aggregate function. A simple

workaround is to define a dummy column in the table expression made

of a constant, as in 1 AS agg\_col, and then in the PIVOT operator apply

the aggregate function to that column: COUNT(agg\_col). In this case

you can also use SUM(agg\_col) as an alternative.

* A PIVOT operator is limited to using only one aggregate function.

The IN clause of the PIVOT operator accepts a static list of spreading

values. It doesn’t support a subquery as input. You need to know ahead

what the distinct values are in the spreading column and specify those

in the IN clause. When the list isn’t known ahead, you can use dynamic

SQL to construct and execute the query string after querying the

distinct values from the data.

#### **Unpivoting Data**

Unpivoting data can be considered the inverse of pivoting. The starting point

is some pivoted data. When unpivoting data, you rotate the input data from a

state of columns to a state of rows. Just like T-SQL supports the native

PIVOT table operator to perform pivoting, it supports a native UNPIVOT

operator to perform unpivoting. Like PIVOT, UNPIVOT is implemented as a

table operator that you use in the FROM clause. The operator operates on the

input table that is provided to its left, which could be the result of other table

operators, like joins. The outcome of the UNPIVOT operator is a table result

that can be used as the input to other table operators that appear to its right.

To demonstrate unpivoting, use as an example a sample table called

Sales.FreightTotals. The following code creates the sample data and queries it

to show its contents:

USE TSQLV4;

DROP IF EXISTS TABLE Sales.FreightTotals;

GO

WITH PivotData AS

(

SELECT

custid, -- grouping column

shipperid, -- spreading column

freight -- aggregation column

FROM Sales.Orders

)

SELECT \*

INTO Sales.FreightTotals

FROM PivotData

PIVOT( SUM(freight) FOR shipperid IN ([1],[2],

[3]) ) AS P;

SELECT \* FROM Sales.FreightTotals;

This code generates the following output, shown here in abbreviated form:

|  |  |  |  |
| --- | --- | --- | --- |
| custid | 1 | 2 | 3 |
| 1 | 95.03 | 61.02 | 69.53 |
| 2 | 43.90 | NULL | 53.52 |
| 3 | 63.09 | 116.56 | 88.87 |
| 4 | 41.95 | 358.54 | 71.46 |
| 5 | 189.44 | 1074.51 | 295.57 |
| 6 | 0.15 | 126.19 | 41.92 |
| 7 | 217.96 | 215.70 | 190.00 |
| 8 | 16.16 | 175.01 | NULL |
| 9 | 341.16 | 419.57 | 597.14 |
| 10 | 129.42 | 162.17 | 502.36 |

As you can see, the source table has a row for each customer and a column

for each shipper (shippers 1, 2, and 3). The intersection of each customer and

shipper has the total freight values. The unpivoting task at hand is to return a

row for each customer and shipper holding the customer ID in one column,

the shipper ID in a second column, and the freight value in a third column.

Unpivoting always takes a set of source columns and rotates those to

multiple rows, generating two target columns: one to hold the source column

values and another to hold the source column names. The source columns

already exist, so their names should be known to you. But the two target

columns are created by the unpivoting solution, so you need to choose names

for those. In our example, the source columns are [1], [2], and [3]. As for

names for the target columns, you need to decide on those. In this case, it

might be suitable to call the values column freight and the names column

shipperid. So remember, in every unpivoting task, you need to identify

the three elements involved:

1. The name you want to assign to the target values column (in this case, freight).
2. The name you want to assign to the target names column (in this case, shipperid).
3. The set of source columns that you’re unpivoting (in this case, [1],[2], [3]).

After you identify these three elements, you use the following query form

to handle the unpivoting task:

SELECT < column list >, < names column >, < values column

>

FROM <xsource table >

UNPIVOT( < values column > FOR < names column > IN(

<source columns> ) ) AS U;

Based on this syntax, the following query addresses the current task:

SELECT custid, shipperid, freight

FROM Sales.FreightTotals

UNPIVOT( freight FOR shipperid IN([1],[2],[3]) ) AS U;

## **System-versioned temporal tables**

Companies often need to be able to track changes to their data. That’s for

purposes like auditing, point in time analysis, comparing current with older

states, slowly-changing dimensions, restoring older state of rows due to an

error, and others. Normally, you can only access the current state of the data

in your tables. If you need to be able to access older states, you need a

solution that tracks changes to the data. One of the solutions that companies

used in the past was to create a history table that keeps older states of

modified rows and triggers that automatically write history data to that table

whenever the current table is modified. In SQL Server 2016 and Azure SQL

Database there’s no need for this anymore thanks to the support for a feature

called *system-versioned temporal tables*. I’ll just use the term *temporal tables*

in short.

SQL Server supports marking a table as a temporal table using an option

called SYSTEM\_VERSIONING and connecting it to a history table. When

you modify data, you interact only with the current table, and SQL Server

behind the scenes writes historical states of modified rows to the history

table. Also when you read data, you query only the current table. You use a

clause called FOR SYSTEM\_TIME that allows you to request earlier states

of the data at a previous point or period of time.

At the date of writing SQL Server currently supports only systemversioned

temporal tables, meaning that the system transaction time

determines the effective time of the change. The SQL Standard also supports

what’s called *application-time period tables* where the application defines the

validity period of a row. With this feature, you can set a change to be

effective in a future period. For example, suppose that there’s a planned price

change of a product during an upcoming holiday period. Then bi-temporal

tables combine system versioning and application versioning.

The following sections cover creating, modifying and querying temporal

tables.

### **Creating tables**

You can mark a table as a temporal table when you create it, or alter an

existing table to become a temporal table. Also, you can have SQL Server

create the related history table for you, or provide an already existing history

table.

There are certain elements that are required in the table definition in order

to mark it as a temporal one:

* A primary key constraint.
* Two DATETIME2 columns with your chosen precision to store the

start and end of the validity period of the row (stored in the UTC time

zone). The period is expressed as a closed-open interval, meaning that

the start is inclusive and the end is exclusive.

* The start column needs to be marked with the clause GENERATED

ALWAYS AS ROW START.

* The end column needs to be marked with the clause GENERATED

ALWAYS AS ROW END.

* The designation of the pair of columns that store the row’s validity

period with the clause PERIOD FOR SYSTEM\_TIME (<startcol>,

<endcol>).

* The table option SYSTEM\_VERSIONING needs to be set to ON.
* A linked history table, which SQL Server can create for you.

As an example, run the following code to create a table called

dbo.Products in the TSQLV4 database as a temporal table (not to be confused

with the already existing Production.Products table):

USE TSQLV4;

CREATE TABLE dbo.Products

(

productid INT NOT NULL

CONSTRAINT PK\_dboProducts PRIMARY KEY(productid),

productname NVARCHAR(40) NOT NULL,

supplierid INT NOT NULL,

categoryid INT NOT NULL,

unitprice MONEY NOT NULL,

-- below are additions related to temporal table

validfrom DATETIME2(3)

GENERATED ALWAYS AS ROW START HIDDEN NOT NULL,

validto DATETIME2(3)

GENERATED ALWAYS AS ROW END HIDDEN NOT NULL,

PERIOD FOR SYSTEM\_TIME (validfrom, validto)

)

WITH

(SYSTEM\_VERSIONING =ON (HISTORY\_TABLE = dbo.ProductsHistory))

Observe the use of the optional HIDDEN property for the period columns.

With this property, the period columns are not returned when using SELECT

\* rather only when referring to them explicitly.

Regarding the history table, if you don’t specify one at all, SQL Server

creates it for you with the naming convention:

MSSQL\_TemporalHistoryFor\_<object\_id>. If you do specify a history table

as in the above example, SQL Server first checks if it already exists. If it

does, SQL Server by default applies a consistency check to verify that there

are no overlapping periods. You can opt not to perform the consistency check

by specifying DATA\_CONSISTENCY\_CHECK = OFF. If the specified

history table doesn’t exist, SQL Server will create it for you using your

chosen name. SQL Server creates the history table with the following

characteristics:

* No primary key.
* A clustered index on (<endcol>, <startcol>), with page compression.
* The period columns are not marked with GENERATED ALWAYS AS

ROW START/END or HIDDEN.

* There’s no designation of period columns with the clause PERIOD

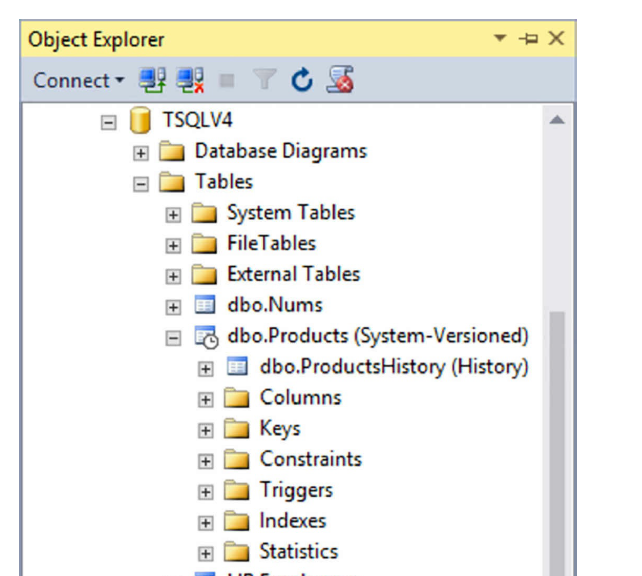
FOR SYSTEM\_TIME.

* The table is not marked with the option SYSTEM\_VERSIONING.

You can see that a table is a temporal table in SQL Server Management

Studio (SSMS). In Object Explorer, expand the Tables folder under the

TSQLV4 database, and then the dbo.Products table, as shown in Figure 2-5.



Observe the table with the clock icon to the left of the current table name

and the fact that it says System-Versioned in parentheses after the table name.

Also, observe the connected history table below the current table, and the fact

that it says History in parentheses after the history table name.

If you need to turn an existing table to become a temporal table, you do so

by first altering the table and adding the period columns with the

aforementioned designations, and then altering the table to mark it as systemversioned

and connecting it to a history table. You will need to add default

constraints to the period columns to set initial values in the existing rows.

The end column in the current table has to store the maximum possible value

in the data type with the select precision. Once the table is marked as a

temporal table, you can drop the default constraints if you wish since SQL

Server will automatically set the period column values moving forward. For

example, if the dbo.Products wasn’t already a temporal table, you would have

turned it to become one by using the following code (don’t actually run this

code since our table is already temporal):

BEGIN TRAN;

ALTER TABLE dbo.Products ADD

validfrom DATETIME2(3) GENERATED ALWAYS AS ROW START

HIDDEN NOT NULL CONSTRAINT DFT\_Products\_validfrom

DEFAULT('19000101'),

validto DATETIME2(3) GENERATED ALWAYS AS ROW END HIDDEN

NOT NULL CONSTRAINT DFT\_Products\_validto

DEFAULT('99991231 23:59:59.999'),

PERIOD FOR SYSTEM\_TIME (validfrom, validto);

ALTER TABLE dbo.Products

SET ( SYSTEM\_VERSIONING = ON ( HISTORY\_TABLE = dbo.ProductsHistory

ALTER TABLE dbo.Products DROP CONSTRAINT DFT\_Products\_validfrom, DFT\_ Products\_validto;

COMMIT TRAN;

SQL Server supports altering temporal tables. You alter the current table

and SQL Server takes care of applying the relevant changes to the history

table for you. For instance, suppose that you want to add a column called

discontinued to the Products table. You alter the current table by running the

following code:

ALTER TABLE dbo.Products

ADD discontinued BIT NOT NULL

CONSTRAINT DFT\_Products\_discontinued DEFAULT(0);

SQL Server adds the same column to the history table with the specified

default value 0 in existing rows, if such were present, but does not add a

default constraint in the history table.

Similarly, if you want to drop a column, you alter only the current table,

and SQL Server takes care of dropping it from the history table. You will

want to start by dropping the default constraint, and then the column. For

example, run the following code to drop the column discontinued from the

Products table:

ALTER TABLE dbo.Products

DROP CONSTRAINT DFT\_Products\_discontinued;

ALTER TABLE dbo.Products

DROP COLUMN discontinued;

SQL Server also drops the column discontinued from the history table for

you.

### **Modifying data**

When you modify data in a temporal table, you do so just like with a normal

table. You submit your changes to the current table, and SQL Server takes

care of writing history rows to the history table when relevant. A couple of

things to remember:

**1.** SQL Server records the change times in the UTC time zone.

**2.** If you apply multiple changes in a transaction, the transaction start time

is considered the effective change time for all changes in the

transaction.

When you insert rows into the current table, SQL Server sets the start

column to the transaction’s start time and the end time to the maximum

possible point in time in the data type. No rows need to be written to the

history table. I ran the examples in this section on November 11th, 2016, so

all of the period columns will have this date in the examples. Suppose that at

14:07:26.263 (UTC) you run the following code:

INSERT INTO dbo.Products(productid, productname,

supplierid, categoryid, unitprice)

SELECT productid, productname, supplierid, categoryid,

unitprice

FROM Production.Products

WHERE productid <= 10;

Query the current table after inserting the data:

SELECT productid, supplierid, unitprice, validfrom,

validto

FROM dbo.Products;

Notice that in order to return the period columns, the query refers to them

explicitly since these columns are marked as hidden in our table.

As mentioned, when you insert data, only the current table is affected.

Query the history table:

SELECT productid, unitprice, validfrom, validto

FROM dbo.ProductsHistory;

This query generates an empty set:

When you delete rows, SQL Server moves the affected rows to the history

table, and sets the end column to the start time of the transaction that applied

the change. Suppose that you run the following code to delete the row for

product 10 at 14:08:41.758:

DELETE FROM dbo.Products

WHERE productid = 10;

An update is handled as a delete plus insert. In other words, the current

table will have the new state of the modified rows, with the start column set

to the change time, and the history table will have the old state of the

modified rows, with the end column set to the change time. For example,

suppose that you run the following code at 14:09:18.584:

UPDATE dbo.Products

SET unitprice \*= 1.05

WHERE supplierid = 3;

Products 6, 7 and 8 are affected.

Run the following code to query the current table after these changes:

SELECT productid, supplierid, unitprice, validfrom,

validto

FROM dbo.Products;

Observe that the old states of both deleted and updated rows are recorded

in the history table, and notice their validity periods start with the insert time

and end with the delete/update time.

As mentioned, when you modify data in a temporal table, the transaction

start time is considered the effective time of the change. If you have multiple

modifications within the same user transaction, they will all have the same

effective modification time. For example, consider the following code, which

modifies three different rows within a single transaction, with five second

intervals between the modifications:

BEGIN TRAN;

PRINT CAST(SYSUTCDATETIME() AS DATETIME2(3));

UPDATE dbo.Products

SET unitprice \*= 0.95

WHERE productid = 1;

WAITFOR DELAY '00:00:05.000';

UPDATE dbo.Products

SET unitprice \*= 0.90

WHERE productid = 2;

WAITFOR DELAY '00:00:05.000';

UPDATE dbo.Products

SET unitprice \*= 0.85

WHERE productid = 3;

COMMIT TRAN;

Run the following code to query the modified rows from the current table:

SELECT productid, supplierid, unitprice, validfrom,

validto

FROM dbo.Products

WHERE productid IN (1, 2, 3);

Notice that all three rows show the same validfrom value, which is the

transaction start time reported earlier. The older state of the modified rows

was written to the history table with the validto value set to the transaction

start time.

If you update the same row multiple times in the same transaction, a

curious thing happens. The original and last states of the row will naturally

have nonzero length intervals as the validity period; however, the in-between

states will have *degenerate intervals* as the validity period where the

validfrom value will be equal to the validto value. That’s the result of using

the transaction start time as the effective time of all changes in the

transaction. Since the validity period is a closed-open interval, conceptually,

it’s as if those states lasted zero time. If you query the history table directly,

you will see those rows that have a degenerate interval as the validity period.

If you query the temporal table using the FOR SYSTEM\_TIME clause to ask

for a previous point or period of time, SQL Server will discard those rows.

As an example, run the following code to update the same row multiple

times in the same transaction:

BEGIN TRAN;

PRINT CAST(SYSUTCDATETIME() AS DATETIME2(3));

UPDATE dbo.Products

SET unitprice = 1.0

WHERE productid = 9;

WAITFOR DELAY '00:00:05.000';

UPDATE dbo.Products

SET unitprice = 2.0

WHERE productid = 9;

WAITFOR DELAY '00:00:05.000';

UPDATE dbo.Products

SET unitprice = 3.0

WHERE productid = 9;

COMMIT TRAN;

The PRINT statement reported the following transaction start time when I

ran this code on my system:

2016-11-01 14:11:38.113

Query the current table:

SELECT productid, unitprice, validfrom, validto

FROM dbo.Products

WHERE productid = 9;

Query history table:

SELECT productid, unitprice, validfrom, validto

FROM dbo.ProductsHistory

WHERE productid = 9;

This query generates the following output, showing that two of the states

have a degenerate interval as the validity period

**Querying data**

You can directly query the current and history tables, and get current and

historical states of the rows. However, to simplify the code, SQL Server

enables you to ask for the state of the data at a previous point or period of

time by querying only the current table and specifying a clause called FOR

SYSTEM\_TIME. Using different subclauses you can specify either a point or

a period during which the rows were valid. Behind the scenes, SQL Server

will retrieve the data from both the current and history tables as needed, and

return a single unified set of rows as the result set of the query. You can also

query views with the FOR SYSTEM\_TIME clause, provided that there’s at

least one underlying table that is a temporal table. SQL Server will propagate

the clause to the underlying temporal tables.

USE TSQLV4;

-- drop tables if exist

IF OBJECT\_ID(N'dbo.Products', N'U') IS NOT NULL

BEGIN

IF OBJECTPROPERTY(OBJECT\_ID(N'dbo.Products', N'U'),

N'TableTemporalType')

ALTER TABLE dbo.Products SET ( SYSTEM\_VERSIONING = OFF );

DROP TABLE IF EXISTS dbo.ProductsHistory, dbo.Products;

END;

GO

-- create and populate Products table

CREATE TABLE dbo.Products

(

productid INT NOT NULL

CONSTRAINT PK\_dboProducts PRIMARY KEY(productid),

productname NVARCHAR(40) NOT NULL,

supplierid INT NOT NULL,

categoryid INT NOT NULL,

unitprice MONEY NOT NULL,

validfrom DATETIME2(3) NOT NULL,

validto DATETIME2(3) NOT NULL

);

INSERT INTO dbo.Products

(productid, productname, supplierid, categoryid,

unitprice, validfrom, VALUES

(1, 'Product HHYDP', 1, 1, 17.10, '20161101 14:10:43.470', '99991231

(2, 'Product RECZE', 1, 1, 17.10, '20161101 14:10:43.470', '99991231

(3, 'Product IMEHJ', 1, 2, 8.50, '20161101 14:10:43.470', '99991231

(4, 'Product KSBRM', 2, 2, 22.00, '20161101 14:07:26.263', '99991231

(5, 'Product EPEIM', 2, 2, 21.35, '20161101 14:07:26.263', '99991231

(6, 'Product VAIIV', 3, 2, 26.25, '20161101 14:09:18.584', '99991231

(7, 'Product HMLNI', 3, 7, 31.50, '20161101 14:09:18.584', '99991231

(8, 'Product WVJFP', 3, 2, 42.00, '20161101 14:09:18.584', '99991231

(9, 'Product AOZBW', 4, 6, 3.00, '20161101 14:11:38.113', '99991231

-- create and populate ProductsHistory table

CREATE TABLE dbo.ProductsHistory

(

productid INT NOT NULL,

productname NVARCHAR(40) NOT NULL,

supplierid INT NOT NULL,

categoryid INT NOT NULL,

unitprice MONEY NOT NULL,

validfrom DATETIME2(3) NOT NULL,

validto DATETIME2(3) NOT NULL,

INDEX ix\_ProductsHistory CLUSTERED(validto, validfrom)

WITH (DATA\_COMPRESSION = PAGE)

);

INSERT INTO dbo.ProductsHistory

(productid, productname, supplierid, categoryid,

unitprice, validfrom, VALUES

( 1, 'Product HHYDP', 1, 1, 18.00, '20161101 14:07:26.263', '20161101

( 2, 'Product RECZE', 1, 1, 19.00, '20161101 14:07:26.263', '20161101

( 3, 'Product IMEHJ', 1, 2, 10.00, '20161101 14:07:26.263', '20161101

( 6, 'Product VAIIV', 3, 2, 25.00, '20161101 14:07:26.263', '20161101

( 7, 'Product HMLNI', 3, 7, 30.00, '20161101 14:07:26.263', '20161101

( 8, 'Product WVJFP', 3, 2, 40.00, '20161101 14:07:26.263', '20161101

( 9, 'Product AOZBW', 4, 6, 97.00, '20161101 14:07:26.263', '20161101

( 9, 'Product AOZBW', 4, 6, 1.00, '20161101 14:11:38.113', '20161101

( 9, 'Product AOZBW', 4, 6, 2.00, '20161101 14:11:38.113', '20161101

(10, 'Product YHXGE', 4, 8, 31.00, '20161101 14:07:26.263', '20161101

-- enable system versioning

ALTER TABLE dbo.Products ADD PERIOD FOR SYSTEM\_TIME

(validfrom, validto);

ALTER TABLE dbo.Products ALTER COLUMN validfrom ADD HIDDEN;

ALTER TABLE dbo.Products ALTER COLUMN validto ADD HIDDEN;

ALTER TABLE dbo.Products

SET ( SYSTEM\_VERSIONING = ON ( HISTORY\_TABLE = dbo.ProductsHistory

Query the current table to see its contents:

SELECT productid, supplierid, unitprice, validfrom,

validto

FROM dbo.Products;

Query the history table to see its contents:

SELECT productid, supplierid, unitprice, validfrom,

validto

FROM dbo.ProductsHistory;

A commonly used subclause of the FOR SYSTEM\_TIME clause is AS OF

@dt. It returns the rows that were valid during the input point in time @dt.

Since the validity period is a closed-open interval, you get the rows where

@dt >= validfrom AND @dt < validto (@dt is on or after validfrom and

before validto). In other words, the validity period starts on or before @dt

and ends after @dt.

Recall that I issued the first insertion into the Products table at

14:07:26.263. Run the following code to query the state of the data at a point

in time prior to the first insertion:

SELECT productid, supplierid, unitprice

FROM dbo.Products FOR SYSTEM\_TIME AS OF '20161101

14:06:00.000';

You get an empty set back.

Run the following code to query the state of the data after the first insertion

and before any other modification:

SELECT productid, supplierid, unitprice

FROM dbo.Products FOR SYSTEM\_TIME AS OF '20161101

14:07:55.000';

This query generates the following output:

productid supplierid unitprice

---------- ----------- ----------

4 2 22.00

5 2 21.35

10 4 31.00

6 3 25.00

7 3 30.00

8 3 40.00

1 1 18.00

2 1 19.00

3 1 10.00

9 4 97.00

You can also query multiple instances of the table, each with a different

point in time as input to the AS OF clause, and this way compare different

states of the data at different points in time. For example, the following query

identifies products that experienced an increase in the unit price between the

points 14:08:55 and 14:10:55, and returns the percent of increase in the price:

SELECT T1.productid, T1.productname,

CAST( (T2.unitprice / T1.unitprice - 1.0) \* 100.0 AS NUMERIC(10, 2)

FROM dbo.Products FOR SYSTEM\_TIME AS OF '20161101 14:08:55.000' AS T1

INNER JOIN dbo.Products FOR SYSTEM\_TIME AS OF '20161101 14:10:55.000'

ON T1.productid = T2.productid

AND T2.unitprice > T1.unitprice;

This query generates the following output:

productid productname pct

---------- -------------- -----

6 Product VAIIV 5.00

7 Product HMLNI 5.00

8 Product WVJFP 5.00

It would appear that three products experience a five percent increase in

their price.

## **Query and output XML data**

XML is a widely used standard for data exchange, that calls Web services

methods, configuration files, and more. This section starts with a short

introduction to XML. After that, you learn how to create XML as a result of a

query by using different flavors of the FOR XML clause. The section finishes

with information on shredding XML to relational tables by using the

OPENXML rowset function.

The following is an example of an XML document, created with the FOR

XML clause of the SELECT statement:

<CustomersOrders>

<Customer custid="1" companyname="Customer NRZBB">

<Order orderid="10692" orderdate="2007-10-

03T00:00:00" />

<Order orderid="10702" orderdate="2007-10-

13T00:00:00" />

<Order orderid="10952" orderdate="2008-03-

16T00:00:00" />

</Customer>

<Customer custid="2" companyname="Customer MLTDN">

<Order orderid="10308" orderdate="2006-09-

18T00:00:00" />

<Order orderid="10926" orderdate="2008-03-

04T00:00:00" />

</Customer>

</CustomersOrders>

As you can see, XML uses *tags* to name parts of an *XML document*. These

parts are called *elements*. Every begin tag, such as <Customer>, must have a

corresponding end tag, in this case </Customer>. If an element has no nested

elements, the notation can be abbreviated to a single tag that denotes the

beginning and end of an element, such as <Order … />. Elements can be

nested, and tags cannot be interleaved; the end tag of a parent element must

be after the end tag of the last nested element. If every begin tag has a

corresponding end tag, and if tags are nested properly, the XML document is

*well-formed*.

XML documents are *ordered*. This does not mean they are ordered by any

specific element value; it means that the position of elements matters. For

example, the element with orderid equal to 10702 in the preceding

example is the second Order element under the first Customer element.

XML is *case-sensitive Unicode text*. You should never forget that XML is

case sensitive. In addition, some characters in XML, such as <, which

introduces a tag, are processed as *markup* and have special meanings. If you

want to include these characters in the values of your XML document, they

must be escaped using an ampersand (&), followed by a special code,

followed by a semicolon (;)

Alternatively, you can use the special XML CDATA section written as <!

[CDATA[...]]>. You can replace the three dots with any character string that

does not include the string literal “]]>”; this will prevent special characters in

the string from being parsed as XML markup.

XML can have a prolog at the beginning of the document, denoting the

XML version and encoding of the document, such as <?xml version=”1.0”

encoding=”ISO-8859-15”?>.

In addition to XML documents, you can also have *XML fragments*. The

only difference between a document and a fragment is that a document has a

single *root node*, like <CustomersOrders> in the preceding example. If you

delete this node, you get an XML fragment.

As you can see from the example, elements can have *attributes*. Attributes

have their own names, and their values are enclosed in quotes. This is

*attribute-centric* presentation. However, you can write XML differently;

every attribute can be a nested element of the original element. This is

*element-centric* presentation.

Element names do not have to be unique, because they can be referred to

by their position; however, to distinguish between elements from different

business areas, different departments, or different companies, you can add

*namespaces*. You declare namespaces used in the root element of an XML

document. You can also use an alias for every single namespace. Then you

prefix element names with a namespace *alias* .

XML is very flexible. There are very few rules for creating a well-formed

XML document. In an XML document, the actual data is mixed with

*metadata* , such as element and attribute names. Because XML is text, it is

very convenient for exchanging data between different systems and even

between different platforms. However, when exchanging data, it becomes

important to have metadata fixed. If you had to import a document with

customers’ orders, as in the preceding examples, every couple of minutes,

you’d definitely want to automate the import process. Imagine how hard

you’d have to work if the metadata changed with every new import.

Many different standards have evolved to describe the metadata of XML

documents. Currently, the most widely used metadata description is with

*XML Schema Description* (XSD) documents. XSD documents are XML

documents that describe the metadata of other XML documents. The schema

of an XSD document is predefined. With the XSD standard, you can specify

element names, data types, and number of occurrences of an element,

constraints, and more.

### **Producing and using XML in queries**

With the T-SQL SELECT statement, you can create all of the XML outputs

that are shown in this section. This section explains how you can convert a

query result set to XML by using the FOR XML clause of the SELECT

statement. Here you will learn about the most useful options and directives of

this clause.

The first option for creating XML from a query result is the RAW option.

The XML created is quite close to the relational (tabular) presentation of the

data. In RAW mode, every row from the returned result set converts to a

single element named row, and columns translate to the attributes of this

element. Here is an example of a query that creates the RAW version of the

FOR XML output:

SELECT Customer.custid, Customer.companyname,

[Order].orderid, [Order].orderdate

FROM Sales.Customers AS Customer

INNER JOIN Sales.Orders AS [Order]

ON Customer.custid = [Order].custid

WHERE Customer.custid <= 2

AND [Order].orderid %2 = 0

ORDER BY Customer.custid, [Order].orderid

FOR XML RAW;

This query generates the following output:

<row custid="1" companyname="Customer NRZBB" orderid="10692" orderdate="10-03" />

<row custid="1" companyname="Customer NRZBB" orderid="10702" orderdate="10-13" />

<row custid="1" companyname="Customer NRZBB" orderid="10952" orderdate="03-16" />

<row custid="2" companyname="Customer MLTDN" orderid="10308" orderdate="09-18" />

<row custid="2" companyname="Customer MLTDN" orderid="10926" orderdate="03-04" />

You can notice that the result is actually an XML fragment and not an

XML document, because the root node is missing. You can enhance the

RAW mode by renaming the row element, adding a root element, including

namespaces, and making the XML returned element-centric.

The FOR XML AUTO option gives you nice XML documents with nested

elements, and it is not complicated to use. In AUTO and RAW modes, you

can use the keyword ELEMENTS to produce element-centric XML. The

WITH NAMESPACES clause, preceding the SELECT part of the query,

defines namespaces and aliases in the returned XML. Here is an example of a

query with the FOR XML AUTO option used, element-centric, with a

namespace defined:

WITH XMLNAMESPACES('ER70761-CustomersOrders' AS co)

SELECT [co:Customer].custid AS [co:custid],

[co:Customer].companyname AS [co:companyname],

[co:Order].orderid AS [co:orderid],

[co:Order].orderdate AS [co:orderdate]

FROM Sales.Customers AS [co:Customer]

INNER JOIN Sales.Orders AS [co:Order]

ON [co:Customer].custid = [co:Order].custid

WHERE [co:Customer].custid <= 2

AND [co:Order].orderid %2 = 0

ORDER BY [co:Customer].custid, [co:Order].orderid

FOR XML AUTO, ELEMENTS, ROOT('CustomersOrders');

The T-SQL table and column aliases in the query are used to produce

element names, prefixed with a namespace. A colon is used in XML to

separate the namespace from the element name. The WHERE clause of the

query limits the output to two customers, with only every second order for

each customer retrieved. The output is quite a nice element-centric XML

document. This query produces the following result (shown here in

abbreviated form):

<CustomersOrders xmlns:co="ER70761-CustomersOrders">

<co:Customer>

<co:custid>1</co:custid>

<co:companyname>Customer NRZBB</co:companyname>

<co:Order>

<co:orderid>10692</co:orderid>

<co:orderdate>2015-10-03</co:orderdate>

</co:Order>

…

<co:custid>2</co:custid>

<co:companyname>Customer MLTDN</co:companyname>

<co:Order>

…

</co:Order>

</co:Customer>

</CustomersOrders>

Note that a proper ORDER BY clause is very important. With the

SELECT statement, you are actually formatting the returned XML. Without

the ORDER BY clause, the order of rows returned is unpredictable, and you

can get a weird XML document with an element repeated multiple times with

just part of nested elements every time.

It is not only the ORDER BY clause that is important; the order of

columns in the SELECT clause also influences the XML returned. SQL

Server uses column order to determine the nesting of elements. The order of

the columns should follow one-to-many relationships. A customer can have

many orders; therefore, you should have customer columns before order

columns in your query.

You might be vexed by the fact that you have to take care of column order;

in a relation, the order of columns and rows is not important. Nevertheless,

you have to realize that the result of your query is not a relation; it is text in

XML format, and parts of your query are used for formatting the text.

There are additional more detailed options for formatting the returned

XML document by using the FOR XML PATH option. In addition, besides

the XML document, you can also return the XSD schema of the document

with the XMLSCHEMA directive.

Besides generating XML from a query, you can also do the opposite:

convert XML to tables. Converting XML to relational tables is known as

*shredding* XML. You shred XML with the OPENXML rowset function.

The OPENXML function provides a rowset over in-memory XML

documents by using the *Document Object Model* (DOM) presentation. Before

parsing the DOM, you need to prepare it. To prepare the DOM presentation

of XML, you need to call the system stored procedure

sys.sp\_xml\_preparedocument. After you shred the document, you must

remove the DOM presentation by using the system procedure

sys.sp\_xml\_removedocument.

The OPENXML function uses the following parameters:

* An XML DOM document handle, returned by sp\_xml\_preparedocument
* An XPath expression to find the nodes you want to map to rows of a rowset returned
* A description of the rowset returned
* Mapping between XML nodes and rowset columns

The document handle is an integer. This is the simplest parameter. The

XPath expression is specified as *rowpattern*, which defines how XML nodes

translate to rows. The path to a node is used as a pattern; nodes below the

selected node define rows of the returned rowset.

You can map XML elements or attributes to rows and columns by using

the WITH clause of the OPENXML function. In this clause, you can specify

an existing table, which is used as a template for the rowset returned, or you

can define a table with syntax similar to the CREATE TABLE statement

syntax.

The OPENXML function accepts an optional third parameter, called flags,

which allows you to specify the mapping used between the XML data and the

relational rowset. The value 1 means attribute-centric mapping, and 2 means

element-centric. Flag value 8 can be combined with values 1 and 2 with a

bitwise OR (|) operator to get both attribute and element-centric mapping.

The XML used for the following OPENXML examples uses attributes and

elements; for example, custid is the attribute and companyname is the

element. The intention of this slightly overcomplicated XML is to show you

the difference between attribute-centric and element-centric mappings. The

following code shreds an XML by using 11 for the flag parameter (8 | 1 | 2).

DECLARE @DocHandle AS INT;

DECLARE @XmlDocument AS NVARCHAR(1000);

SET @XmlDocument = N'

<CustomersOrders>

<Customer custid="1">

<companyname>Customer NRZBB</companyname>

<Order orderid="10692">

<orderdate>2015-10-03T00:00:00</orderdate>

</Order>

<Order orderid="10702">

<orderdate>2015-10-13T00:00:00</orderdate>

</Order>

<Order orderid="10952">

<orderdate>2016-03-16T00:00:00</orderdate>

</Order>

</Customer>

<Customer custid="2">

<companyname>Customer MLTDN</companyname>

<Order orderid="10308">

<orderdate>2014-09-18T00:00:00</orderdate>

</Order>

<Order orderid="10926">

<orderdate>2016-03-04T00:00:00</orderdate>

</Order>

</Customer>

</CustomersOrders>';

-- Create an internal representation

EXEC sys.sp\_xml\_preparedocument @DocHandle OUTPUT, @XmlDocument;

-- Attribute- and element-centric mapping

-- Combining flag 8 with flags 1 and 2

SELECT \*

FROM OPENXML (@DocHandle, '/CustomersOrders/Customer', 11)

WITH (custid INT,

companyname NVARCHAR(40));

-- Remove the DOM

EXEC sys.sp\_xml\_removedocument @DocHandle;

# Program databases by using Transact-SQL

This chapter covers programmability features in T-SQL. It starts with

programmability objects like views, user-defined functions, and stored

procedures. It then covers handling errors with the TRY-CATCH construct,

and working with transactions. The chapter completes with coverage of

handling of data types and treatment of NULLs.

## **Create database programmability objects by using Transact-SQL**

This skill focuses on working with programmability objects using T-SQL. It

covers simplifying and reusing query logic using views; encapsulating single

expressions, queries, and multiple statements in user-defined functions; and

lastly, working with stored procedures.

### **Views**

A view is a reusable named query, or table expression, whose definition is

stored as an object in the database. It is accessible to users who were granted

with permissions to query it. You can also modify data in underlying tables

through it.

Views enable you to simplify the database’s data model for users by

presenting them with customized views of the data. For example, views can

join underlying tables to simplify reporting queries. Instead of repeating

complex queries in multiple places in the code, they can achieve reusability

by querying the view. If you need to alter the structure of tables, you can use

views to provide the application with backward compatible representation of

the data. Views can also be used as a security layer, by granting users with

access to the view but not to the underlying tables. This way, users can see

only the customized representation of the data that you want them to see.

**Working with views**

The following code creates a view called Sales.OrderTotals in the TSQLV4 database:

USE TSQLV4;

GO

CREATE OR ALTER VIEW Sales.OrderTotals

WITH SCHEMABINDING

AS

SELECT

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate,

SUM(OD.qty) AS qty,

CAST(SUM(OD.qty \* OD.unitprice \* (1 - OD.discount))

AS NUMERIC(12, 2)) AS val

FROM Sales.Orders AS O

INNER JOIN Sales.OrderDetails AS OD

ON O.orderid = OD.orderid

GROUP BY

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate;

GO

This view computes total order quantities and net values by joining the

Sales.Orders and Sales.OrderDetails tables, grouping the data by the order

elements, and aggregating the quantities and net values.

Notice the GO batch separator after the USE TSQLV4 statement. The

CREATE OR ALTER VIEW statement must be the first statement in the

batch. The same applies to the CREATE VIEW and ALTER VIEW

statements.

Also, notice the use of the SCHEMABINDING option in the view’s

header. This option prevents structural changes to dependent tables and

columns while the view exists. This option is not set by default, but there are

situations where it’s mandatory, such as if you want to create an index on the

view. Some, including myself, see this option as a best practice that increases

system stability since it helps you avoid having objects in the database that

depend on nonexistent or altered objects. However, you do need to be aware

that the use of SCHEMABINDING does increase the complexity of handling

structural changes, such as ones done as part of application upgrades. Such

changes require dropping and recreating schema-bound objects before and

after the change, respectively.

Recall the discussion about table expressions in Chapter 2, Skill 2.2. I

explained that a view is one of the kinds of table expressions that T-SQL

supports in addition to derived tables, CTEs, and inline table-valued

functions. I also explained that the inner query has to follow three

requirements:

* All columns must have names. This means that if the column is a result

of a computation, you must assign it with an alias.

* All column names must be unique. This means that if you join tables

and you want to return columns with the same name from the different

tables, you have to assign the columns with different aliases.

* The inner query is not allowed to have an ORDER BY clause, unless

this clause supports a TOP or OFFSET-FETCH filter. Either way,

unless the outer query against the view has its own ORDER BY clause,

presentation ordering for the rows in the result is not guaranteed.

If you need to assign aliases to target columns, you can use an inline

aliasing form where you assign the alias as part of the expression, such as in

the example above for the result columns qty and val. As an alternative, you

could use an external aliasing form where you specify the target column

names right after the view name in parentheses, like so:

CREATE OR ALTER VIEW Sales.OrderTotals

(orderid, custid, empid, shipperid, orderdate, requireddate, shippeddate,

qty, val)...

Run the following code to query the view that you just created:

SELECT orderid, orderdate, custid, empid, val

FROM Sales.OrderTotals;

SQL Server typically doesn’t persist the view’s result anywhere; rather it

internally keeps the query text and some additional metadata information

about the view and its columns in catalog objects. When you query the view,

SQL Server expands the view definition and queries the underlying tables.

If you want to get the definition of an existing view (or other module), use

the OBJECT\_DEFINITION function, like so:

PRINT OBJECT\_DEFINITION(OBJECT\_ID(N’Sales.OrderTotals’));

T-SQL supports defining views based on a query against a CTE. As an

example, the following code defines a view called

Sales.CustLast5OrderDates based on a query that for each customer, returns

the last five distinct order dates:

CREATE OR ALTER VIEW Sales.CustLast5OrderDates

WITH SCHEMABINDING

AS

WITH C AS

(

SELECT

custid, orderdate,

DENSE\_RANK() OVER(PARTITION BY custid ORDER BY orderdate DESC) AS FROM Sales.Orders

)

SELECT custid, [1], [2], [3], [4], [5]

FROM C

PIVOT(MAX(orderdate) FOR pos IN ([1], [2], [3], [4], [5])) AS P;

GO

The query that defines the CTE named C returns for each order the customer ID, order date, and dense rank of the order date (descending) for the customer. The outer query against C groups the data implicitly by the customer ID, and pivots the five most recent distinct order dates using the artificial MAX aggregate. The aggregate is artificial in the sense that for each customer and position there’s only one distinct order date, but the PIVOT syntax requires you to use an aggregate function to return it.

Notice the use of square brackets to delimit the target column names

representing the positions of the order dates. In T-SQL, irregular identifiers

such as ones that start with a digit must be delimited. If you remove the

delimiters from the columns in the IN clause, you get a syntax error. If you

remove them from the columns in the SELECT list, instead of getting the

values of the columns [1], [2] and on, which represent order dates, you get

back the constants 1, 2, and on. Try it.

Query the view:

SELECT custid, [1], [2], [3], [4], [5]

FROM Sales.CustLast5OrderDates;

**View attributes**

As you have noticed, all view definitions in my examples specify the

SCHEMABINDING option. This option prevents structural changes to

underlying objects while the view exists. To demonstrate what can happen

without this option, run the following code to alter the view from the last

example in the previous section to not include the SCHEMABINDING

option:

CREATE OR ALTER VIEW Sales.USACusts

AS

SELECT

custid, companyname, contactname, contacttitle, address,city, region, postalcode, country, phone, fax

FROM Sales.Customers

WHERE country = N’USA’;

GO

It’s important to remember that when you alter a view, either with the

ALTER VIEW command, or with the CREATE OR ALTER VIEW

command, you have to specify again any view attributes that you want to

preserve. The main benefit in altering a view, as opposed to dropping and

recreating it, is that permissions are preserved.

Now that our view does not include the SCHEMABINDING option,

you’re allowed to alter the underlying table definition. Run the following

code to drop the address column from the table (in a transaction that you roll

back to undo the change):

BEGIN TRAN;

ALTER TABLE Sales.Customers DROP COLUMN address;

ROLLBACK TRAN; -- undo change

The code runs successfully.

Alter the view to include the SCHEMABINDING attribute:

CREATE OR ALTER VIEW Sales.USACusts

WITH SCHEMABINDING

AS

SELECT

custid, companyname, contactname, contacttitle, address, city, region, postalcode, country, phone, fax

FROM Sales.Customers

WHERE country = N’USA’;

GO

Try to drop the column again:

ALTER TABLE Sales.Customers DROP COLUMN address;

This time the attempt is rejected, and you get the following errors:

Msg 5074, Level 16, State 1, Line 247

The object ‘USACusts’ is dependent on column ‘address’.

Msg 4922, Level 16, State 9, Line 247

ALTER TABLE DROP COLUMN address failed because one or more

objects access this column.

T-SQL supports a view attribute called ENCRYPTION that causes SQL

Server to obfuscate the object definition that is stored internally. Without this

attribute, you can get the object definition by using the

OBJECT\_DEFINITION function, like so:

SELECT OBJECT\_DEFINITION(OBJECT\_ID(N’Sales.USACusts’));

This code returns the requested view’s definition. Alternatively you can

use the sp\_helptext procedure, or query the sys.syscomments view directly.

Next, alter the view definition to include the ENCRYPTION attribute, like so

(don’t forget to re-specify the SCHEMABINDING option otherwise the view

is altered without it):

CREATE OR ALTER VIEW Sales.USACusts

WITH SCHEMABINDING, ENCRYPTION

AS

SELECT

custid, companyname, contactname, contacttitle, address, city, region, postalcode, country, phone, fax

FROM Sales.Customers

WHERE country = N’USA’;

GO

Run the following code to try and get the object definition:

SELECT OBJECT\_DEFINITION(OBJECT\_ID(N’Sales.USACusts’));

This time the code returns a NULL.

**Modifying data through views**

You’re not limited to only issuing SELECT queries against table expressions,

such as views, rather, you’re also allowed to issue modification statements

against those. Because a table expression is a reflection of data from some

underlying tables, it’s those underlying tables that are affected by the

modification. If you’re modifying the data through a view, you do need

appropriate permissions assigned to you against the view.

To demonstrate this capability, I use the Sales.USACusts view, which you

create by running the following code:

CREATE OR ALTER VIEW Sales.USACusts

WITH SCHEMABINDING

AS

SELECT

custid, companyname, contactname, contacttitle, address, city, region, postalcode, country, phone, fax

FROM Sales.Customers

WHERE country = N’USA’;

GO

Run the following code to add a customer to the Sales.Customers table

through the view:

INSERT INTO Sales.USACusts(companyname, contactname,

contacttitle, address,city, region, postalcode, country, phone, fax)

VALUES(N’Customer AAAAA’, N’Contact AAAAA’, N’Title AAAAA’,

N’Address AAAAA’,N’Redmond’, N’WA’, N’11111’, N’USA’, N’111-1111111’, N’111-1111111’);

Query the underlying table to make sure that the new row made it there:

SELECT custid, companyname, country

FROM Sales.Customers

WHERE custid = SCOPE\_IDENTITY();

You get the following output confirming that it did:

custid companyname country

----------- ---------------------------------------- -----

----------

92 Customer AAAAA USA

There are some very sensible restrictions on modifications through table

expressions. One of them is that if the inner query joins multiple tables,

INSERT and UPDATE statements are allowed to affect only one target table

at a time. Also, you cannot insert rows through a table expression if it doesn’t

include at least one column from the underlying table that doesn’t somehow

get its values automatically (for example by allowing NULLs or having a

default value).

Note that normally, you are allowed to insert and update rows through the

view even if the modification contradicts the inner query’s filter. In our

example, you can insert customers from a non-US country, or update an

existing customer’s country to one other than the US. The effect seems

strange because the underlying Sales.Customers table becomes modified, but

when you query the view, you won’t see the modified rows because they

don’t satisfy the view’s filter anymore.

As an example, run the following code to add a customer from the UK

through the view:

INSERT INTO Sales.USACusts( companyname, contactname,

contacttitle, address,city, region, postalcode, country, phone, fax)

VALUES( N’Customer BBBBB’, N’Contact BBBBB’, N’Title

BBBBB’, N’Address BBBBB’, N’London’, NULL, N’22222’, N’UK’, N’222-2222222’, N’222- 2222222’);

The code runs successfully, and the row is added to the underlying table.

Query the view to look for the new customer:

SELECT custid, companyname, country

FROM Sales.USACusts

WHERE custid = SCOPE\_IDENTITY();

You get an empty set back:

Query the underlying table to look for the new customer:

SELECT custid, companyname, country

FROM Sales.Customers

WHERE custid = SCOPE\_IDENTITY();

This time you do get the new customer row back:

custid companyname country

----------- ---------------------------------------- -----

----------

93 Customer BBBBB UK

T-SQL supports an option called CHECK OPTION that prevents inserting

or updating rows through the view if the change contradicts the inner query’s

filter. This option has a somewhat similar effect to a CHECK constraint in a

table. You add it at the end of the inner query, like so:

CREATE OR ALTER VIEW Sales.USACusts

WITH SCHEMABINDING

AS

SELECT

custid, companyname, contactname, contacttitle, address,city, region, postalcode, country, phone, fax

FROM Sales.Customers

WHERE country = N’USA’

WITH CHECK OPTION;

GO

Run the following code to try again to add a customer from the UK

through the view:

INSERT INTO Sales.USACusts(companyname, contactname,

contacttitle, address,city, region, postalcode, country, phone, fax)

VALUES(N’Customer CCCCC’, N’Contact CCCCC’, N’Title CCCCC’,

N’Address CCCCC’,N’London’, NULL, N’33333’, N’UK’, N’333-3333333’, N’333-3333333’);

This time the code fails and you get the following error:

Msg 550, Level 16, State 1, Line 352

The attempted insert or update failed because the target

view either specifies WITH CHECK OPTION or spans a view

that specifies WITH CHECK OPTION and one or more rows

resulting from the operation did not qualify under the

CHECK OPTION constraint.

The statement has been terminated.

Curiously, the CHECK option in a view does differ from a CHECK

constraint in a table in how the two handle NULLs, if those are allowed in the

target column. For example, suppose that the country column allowed

NULLs. A CHECK constraint based on the predicate country = N’USA’

would have allowed rows with a NULL country, whereas a view with a filter

based on the same predicate and the CHECK option would have regected

such rows.

**Indexed views**

Recall that when you query a view, SQL Server expands the view definition,

and optimizes the code against the underlying tables. I demonstrated this

earlier. But what if the inner query is quite expensive, and you query the view

frequently? You want to avoid the repetition of the work that is involved

every time you query the view. To achieve this, you create a clustered index

on the view, and this way you persist the view’s result within the clustered

index B-tree structure. There is an extra cost every time you modify data in

the underlying tables because SQL Server needs to modify the indexed view,

like it would need to modify other indexes on the tables. So, similar to

regular indexes, the tradeoff is faster queries at the cost of extra write cost

and space.

To demonstrate the use of indexed views, I use the Sales.OrderTotals view

from the previous examples, which you create by running the following code:

CREATE OR ALTER VIEW Sales.OrderTotals

WITH SCHEMABINDING

AS

SELECT

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate,

SUM(OD.qty) AS qty,

CAST(SUM(OD.qty \* OD.unitprice \* (1 - OD.discount))

AS NUMERIC(12, 2)) AS val

FROM Sales.Orders AS O

INNER JOIN Sales.OrderDetails AS OD

ON O.orderid = OD.orderid

GROUP BY

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate;

GO

The first index that you create on the view has to be clustered and unique.

Run the following code to try and create such an index on the view:

CREATE UNIQUE CLUSTERED INDEX idx\_cl\_orderid ON

Sales.OrderTotals(orderid);

As it turns out, there are restrictions and requirements to allow you to

create an indexed view. One of them is that the view header has to have the

SCHEMABINDING attribute, which in our case is fulfilled. Another is that if

the query is a grouped query, it has to include the COUNT\_BIG aggregate.

SQL Server needs to track the group row counts to know when a group needs

to be eliminated as a result of deletes or updates of underlying detail rows.

Consequently, your attempt to create the index fails, and you get the

following error:

Msg 10138, Level 16, State 1, Line 98

Cannot create index on view ‘TSQLV4.Sales.OrderTotals’

because its select list does not

include a proper use of COUNT\_BIG. Consider adding

COUNT\_BIG(\*) to select list.

To satisfy this requirement, you alter the view definition and add the

COUNT\_BIG function by running the following code:

CREATE OR ALTER VIEW Sales.OrderTotals

WITH SCHEMABINDING

AS

SELECT

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate,

SUM(OD.qty) AS qty,

CAST(SUM(OD.qty \* OD.unitprice \* (1 - OD.discount))

AS NUMERIC(12, 2)) AS val,

COUNT\_BIG(\*) AS numorderlines

FROM Sales.Orders AS O

INNER JOIN Sales.OrderDetails AS OD

ON O.orderid = OD.orderid

GROUP BY

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate;

GO

Try to create the index again:

CREATE UNIQUE CLUSTERED INDEX idx\_cl\_orderid ON

Sales.OrderTotals(orderid);

The attempt fails again with the following error:

Msg 8668, Level 16, State 0, Line 124

Cannot create the clustered index ‘idx\_cl\_orderid’ on view

‘TSQLV4.Sales.OrderTotals’ because the select list of the

view contains an expression on result of aggregate

function or grouping column. Consider removing expression

on result of aggregate function or grouping column from

select list.

As it turns out, you’re not allowed to manipulate the result of an aggregate

calculation, and our query casts the total order value, which is computed with

the SUM aggregate, to NUMERIC(12, 2). In order to be able to create the

index, you need to remove the manipulation that is applied by the CAST

function, like so:

CREATE OR ALTER VIEW Sales.OrderTotals

WITH SCHEMABINDING

AS

SELECT

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate,

SUM(OD.qty) AS qty,

SUM(OD.qty \* OD.unitprice \* (1 - OD.discount)) AS val,

COUNT\_BIG(\*) AS numorderlines

FROM Sales.Orders AS O

INNER JOIN Sales.OrderDetails AS OD

ON O.orderid = OD.orderid

GROUP BY

O.orderid, O.custid, O.empid, O.shipperid, O.orderdate,

O.requireddate, O.shippeddate;

GO

Try again to create the index:

CREATE UNIQUE CLUSTERED INDEX idx\_cl\_orderid ON

Sales.OrderTotals(orderid);

This time the index is created successfully.

To recap, the view has to include SCHEMABINDING, the first index has

to be clustered and unique, if the query is a grouped query it has to include

the COUNT\_BIG aggregate functions, and you’re not allowed to manipulate

the result of aggregate functions. You can find a more complete list of

requirements and restriction at *https://msdn.microsoft.com/enus/*

*library/ms191432.aspx*.

Once you successfully created a clustered index on a view, you’re allowed

to create additional nonclustered indexes. Run the following code to create a

number of nonclustered indexes on the Sales.OrderTotal view:

CREATE NONCLUSTERED INDEX idx\_nc\_custid ON

Sales.OrderTotals(custid);

CREATE NONCLUSTERED INDEX idx\_nc\_empid ON

Sales.OrderTotals(empid);

CREATE NONCLUSTERED INDEX idx\_nc\_shipperid ON

Sales.OrderTotals(shipperid);

CREATE NONCLUSTERED INDEX idx\_nc\_orderdate ON

Sales.OrderTotals(orderdate);

CREATE NONCLUSTERED INDEX idx\_nc\_shippeddate ON

Sales.OrderTotals(shippeddate);

Run the following code to query the view:

SELECT orderid, custid, empid, shipperid, orderdate,

requireddate, shippeddate, qty, val, numorderlines

FROM Sales.OrderTotals;

As long as you’re running the code on an Enterprise or Developer edition

of SQL Server, the optimizer considers using indexes on the view without

any special instructions.

### **User-defined functions**

A user-defined function (UDF) is a routine that accepts parameters, applies

calculations, and returns either a scalar-valued or a table-valued result. SQL

Server supports developing functions using either T-SQL, or the common

language runtime (CLR). The focus of the exam—and hence the book’s—is

the T-SQL kind.

A user-defined function can appear in places in your code where a scalar valued

or table-valued expression can appear, such as in a query, a computed

column, and a CHECK constraint. It can even appear in the definition of

another user-defined function. You can use a user-defined function to replace

a stored procedure when you want to be able to query its result. You can use

it as an alternative to a view with parameters, since views don’t support

parameters. You can even use a user-defined function to query an indexed

view, and with parameter support, improve its functionality. You can also use

a user-defined function to define a filter for a security policy as part of an

implementation of row level security.

There are a number of restrictions and limitations on user-defined

functions. Within user-define functions you cannot:

* Use error handling
* Modify data (other than in table variables)
* Use data definition language (DDL)
* Use temporary tables
* Use dynamic SQL

Some of the examples in this section use a table called dbo.Employees (not

to be confused with HR.Employees from the sample database). Run the

following code to create this table and populate it with sample data:

SET NOCOUNT ON;

USE TSQLV4;

DROP TABLE IF EXISTS dbo.Employees;

GO

CREATE TABLE dbo.Employees

(

empid INT NOT NULL CONSTRAINT PK\_Employees PRIMARY KEY,

mgrid INT NULL

CONSTRAINT FK\_Employees\_Employees REFERENCES dbo.Employees,

empname VARCHAR(25) NOT NULL,

salary MONEY NOT NULL,

CHECK (empid <> mgrid)

);

INSERT INTO dbo.Employees(empid, mgrid, empname, salary)

VALUES(1, NULL, ‘David’, $10000.00),

(2, 1, ‘Eitan’, $7000.00),

(3, 1, ‘Ina’, $7500.00),

(4, 2, ‘Seraph’, $5000.00),

(5, 2, ‘Jiru’, $5500.00),

(6, 2, ‘Steve’, $4500.00),

(7, 3, ‘Aaron’, $5000.00),

(8, 5, ‘Lilach’, $3500.00),

(9, 7, ‘Rita’, $3000.00),

(10, 5, ‘Sean’, $3000.00),

(11, 7, ‘Gabriel’, $3000.00),

(12, 9, ‘Emilia’ , $2000.00),

(13, 9, ‘Michael’, $2000.00),

(14, 9, ‘Didi’, $1500.00);

CREATE UNIQUE INDEX idx\_unc\_mgr\_emp\_i\_name\_sal ON

dbo.Employees(mgrid, empid)

INCLUDE(empname, salary);

T-SQL supports three kinds of user-defined functions: scalar, inline table

valued and multistatement table valued. The upcoming sections cover these

three types.

#### **Scalar user-defined functions**

A scalar user-defined function accepts parameters, applies calculations, and

returns a single value. It has a body with flow that can have multiple

statements, including queries, and eventually it must invoke a RETURN

clause to return the result value. The header of the function defines the input

parameters as well as the return type using a RETURNS clause.

As an example, the following code defines a function called

dbo.SubtreeTotalSalaries:

CREATE OR ALTER FUNCTION dbo.SubtreeTotalSalaries(@mgr AS

INT)

RETURNS MONEY

WITH SCHEMABINDING

AS

BEGIN

DECLARE @totalsalary AS MONEY;

WITH EmpsCTE AS

(

SELECT empid, salary

FROM dbo.Employees

WHERE empid = @mgr

UNION ALL

SELECT S.empid, S.salary

FROM EmpsCTE AS M

INNER JOIN dbo.Employees AS S

ON S.mgrid = M.empid

)

SELECT @totalsalary = SUM(salary)

FROM EmpsCTE;

RETURN @totalsalary;

END;

GO

The header of the function defines an input parameter called @mgr

representing an input manager ID, and MONEY as the returned type. It

specifies the SCHEMABINDING option to prevent structural changes to

dependent objects (the Employees table in our case). The body of the

function resides between the mandatory BEGIN and END clauses. The code

in the function’s body declares a local variable called @totalsalary. It then

uses a recursive query that identifies the input manager’s subordinates (direct

and indirect). The outer statement of the CTE then assigns the total salaries of

the input manager and all identified subordinates to the variable. Finally, the

code returns the value stored in @totalsalary.

Use the following code to test the function, asking for the total salaries of

the subtree of manager 8 (Lilach):

SELECT dbo.SubtreeTotalSalaries(8) AS subtreetotal;

This code returns the following output:

Subtreetotal

---------------------

3500.00

With most object types, T-SQL allows you to omit the schema name when

referring to the object, in which case it uses implicit schema name resolution.

With scalar UDFs, you must use the two-part name including the schema. For

instance, try calling the function again, but this time without the schema:

SELECT SubtreeTotalSalaries(8) AS subtreetotal;

You get the following error:

Msg 195, Level 15, State 10, Line 553

‘SubtreeTotalSalaries’ is not a recognized built-in

function name.

SQL Server looks for a built-in function with the specified name and since

it can’t find one, it fails.

As mentioned, you can invoke a user-defined function as part of a query.

For example, the following code queries the Employees table, and invokes

the function for each employee to return the total salaries of the respective

employee’s subtree:

SELECT empid, mgrid, empname, salary,

dbo.SubtreeTotalSalaries(empid) AS subtreetotal

FROM dbo.Employees;

#### **Inline table-valued user-defined functions**

An inline table-valued user-defined function is very similar in concept to a

view in the sense that it’s based on a single query, and you interact with it

like a table expression, only unlike a view, it supports input parameters. So

you could think of such a function as a parameterized view.

The reason that it’s called an inline function is because SQL Server inlines,

or expands, the inner query definition, and constructs an internal query

directly against the underlying tables. The inlining process includes replacing

the inner query’s references to the input parameters with the passed constants

(what’s known as parameter embedding).

As an example, run the following code to create an inline function called

GetPage:

CREATE OR ALTER FUNCTION dbo.GetPage(@pagenum AS BIGINT,

@pagesize AS BIGINT)

RETURNS TABLE

WITH SCHEMABINDING

AS

RETURN

WITH C AS

(

SELECT ROW\_NUMBER() OVER(ORDER BY orderdate,

orderid) AS rownum,

orderid, orderdate, custid, empid

FROM Sales.Orders

)

SELECT rownum, orderid, orderdate, custid, empid

FROM C

WHERE rownum BETWEEN (@pagenum - 1) \* @pagesize + 1 AND @pagenum \* @pagesize;

GO

Notice that the function’s header defines the input parameters and says that

it returns a table result (RETURN TABLE). There’s no body to the function

(no BEGIN-END block), rather just a RETURN clause with a query.

This function implements a paging solution where you pass a page number

and page size, and the function returns orders from the desired page. The

code defines a CTE called C based on a query that computes row numbers for

orders, based on orderdate and orderid ordering. The outer query then filters

only the rows from C with the row numbers that fall in the requested page.

The starting row number is based on the expression (@pagenum - 1) \*

@pagesize + 1, and the ending row number is based on the expression

pagenum \* @pagesize. For example, with a page number 3, and a page size

of 12, the first row number is 25, and the last row number is 36.

Run the following query to test the function, asking for page 3 with a page

size of 12:

SELECT rownum, orderid, orderdate, custid, empid

FROM dbo.GetPage(3, 12) AS T;

Recall from Chapter 1 that T-SQL supports a built-in feature for ad-hoc

paging in the form of a filter called OFFSET-FETCH. With this filter, you

can simplify the solution for the task at hand by using the following function

definition instead:

CREATE OR ALTER FUNCTION dbo.GetPage(@pagenum AS BIGINT,

@pagesize AS BIGINT)

RETURNS TABLE

WITH SCHEMABINDING

AS

RETURN

SELECT ROW\_NUMBER() OVER(ORDER BY orderdate, orderid)

AS rownum,

orderid, orderdate, custid, empid

FROM Sales.Orders

ORDER BY orderdate, orderid

OFFSET (@pagenum - 1) \* @pagesize ROWS FETCH NEXT

@pagesize ROWS ONLY;

GO

With this solution you don’t need to use a CTE that defines row numbers

and then an outer query that handles the filter, you can handle both tasks in

one query. Run the following code to test the altered function:

SELECT rownum, orderid, orderdate, custid, empid

FROM dbo.GetPage(3, 12) AS T;

You get the same result as before.

As a more complex example for an inline table-valued user-defined

function, suppose that you need to implement a function called GetSubtree

that accepts a manager ID as input (call it @mgr), and an optional parameter

to limit the number of levels (call it @maxlevels); the function should return

the set of all subordinates of the input manager, applying the level limit if one

was specified. The function should return a NULL as the manager ID of the

input manager.

Run the following code to implement the GetSubtree function as an inline

table-valued one:

DROP FUNCTION IF EXISTS dbo.GetSubtree;

GO

CREATE FUNCTION dbo.GetSubtree(@mgr AS INT, @maxlevels AS

INT = NULL)

RETURNS TABLE

WITH SCHEMABINDING

AS

RETURN

WITH EmpsCTE AS

(

SELECT empid, CAST(NULL AS INT) AS mgrid, empname,

salary, 0 as lvl,

CAST(‘.’ AS VARCHAR(900)) AS sortpath

FROM dbo.Employees

WHERE empid = @mgr

UNION ALL

SELECT S.empid, S.mgrid, S.empname, S.salary,

M.lvl +

1 AS lvl,

CAST(M.sortpath + CAST(S.empid AS VARCHAR(10))

+ ‘.’ AS VARCHAR(900)) AS sortpath

FROM EmpsCTE AS M

INNER JOIN dbo.Employees AS S

ON S.mgrid = M.empid

AND (M.lvl < @maxlevels OR @maxlevels IS NULL)

)

SELECT empid, mgrid, empname, salary, lvl, sortpath

FROM EmpsCTE;

The function uses a recursive CTE to handle the task. The anchor member

returns the row for the input manager, along with the constant manager ID

NULL, the level 0, and a sort path that is made of a separator plus the current

employee ID plus another separator.

The recursive member joins the managers from the previous round

(identified with the recursive reference to the CTE name) with the Employees

table to return direct subordinates, provided the level (depth) did not exceed

the specified maximum number of levels, if one was specified. The

subordinate’s level is computed as the corresponding manager’s level plus 1,

and the subordinate’s sort path is computed by concatenating the manager’s

path with the current employee ID plus a separator.

Note that corresponding columns in the anchor and the recursive queries

must have identical types, including length and precision. Since the manager

ID of the input manager is supposed to be set to the constant NULL, and the

manager IDs of the subordinates are to be integer typed values, you need to

explicitly convert the NULL constant to INT in the anchor query. Similarly,

since the column sortpath in both the anchor and recursive queries have to

have the same type and length, the code explicitly converts the values in both

queries to VARCHAR(900).

The following example demonstrates using the function to return the

subtree of manager 3, without limiting the number of levels:

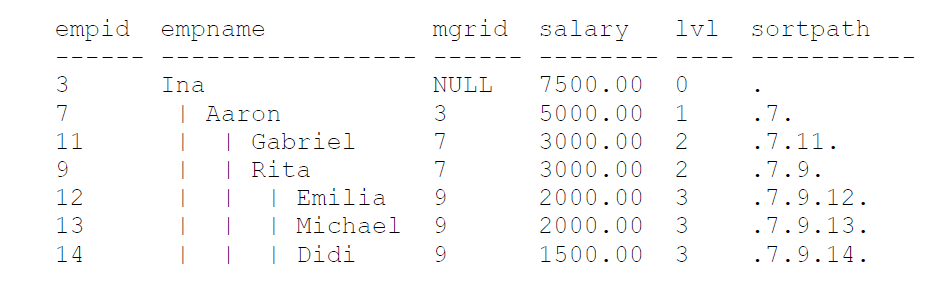
SELECT empid, REPLICATE(‘ | ‘, lvl) + empname AS emp,

mgrid, salary, lvl, sortpath

FROM dbo.GetSubtree(3, NULL) AS T

ORDER BY sortpath;

This code generates the following output:



Ordering the result by the sortpath column guarantees that the presentation

order of the result reflects topological sort order, meaning that a manager

always shows up before his or her subordinates. Using the REPLICATE

function the code replicates a string lvl times to achieve a visual indentation

effect that reflects the level of the current node with respect to the root of the

subtree. It’s pretty!

#### **Multistatement table-valued user-defined functions**

A multistatement table-valued user-defined function is a table function, so

from the user’s perspective, it’s used as a source table in a query much like

an inline table-valued function is used. However, instead of being based on a

single query, the multistatement function declares a returned table variable in

its header, and then its body is responsible for filling the returned table

variable with rows. Whenever you query the function, behind the scenes SQL

Server creates the table variable that is defined in the function’s header, runs

the flow in the function’s body to fill it with rows, and then as soon as the

function executes the RETURN command, SQL Server hands the table

variable to the calling query.

As an example, run the following code to create an alternative

implementation of the GetSubtree function, this time as a multistatement

table-valued function:

DROP FUNCTION IF EXISTS dbo.GetSubtree;

-- cannot use CREATE OR ALTER to change the function type

GO

CREATE FUNCTION dbo.GetSubtree (@mgrid AS INT, @maxlevels

AS INT = NULL)

RETURNS @Tree TABLE

(

empid INT NOT NULL PRIMARY KEY,

mgrid INT NULL,

empname VARCHAR(25) NOT NULL,

salary MONEY NOT NULL,

lvl INT NOT NULL,

sortpath VARCHAR(892) NOT NULL ,

INDEX idx\_lvl\_empid\_sortpath NONCLUSTERED(lvl, empid, sortpath)

)

WITH SCHEMABINDING

AS

BEGIN

DECLARE @lvl AS INT = 0;

-- insert subtree root node into @Tree

INSERT INTO @Tree(empid, mgrid, empname, salary, lvl,

sortpath)

SELECT empid, NULL AS mgrid, empname, salary, @lvl

AS lvl, ‘.’ AS FROM dbo.Employees

WHERE empid = @mgrid;

WHILE @@ROWCOUNT > 0 AND (@lvl < @maxlevels OR

@maxlevels IS NULL)

BEGIN

SET @lvl += 1;

-- insert children of nodes from prev level into

Tree

INSERT INTO @Tree(empid, mgrid, empname, salary,

lvl, sortpath)

SELECT S.empid, S.mgrid, S.empname, S.salary,

@lvl AS lvl, M.sortpath + CAST(S.empid AS

VARCHAR(10)) + ‘.’ AS sortpath

FROM dbo.Employees AS S

INNER JOIN @Tree AS M

ON S.mgrid = M.empid AND M.lvl = @lvl - 1;

END;

RETURN;

END;

GO

The header of the function defines a table variable called @Tree as the

returned value. Then the code in the body of the function (observe the

BEGIN-END block) starts by declaring a level counter called @lvl and

initializes it with 0. The code continues to insert the row for the input

manager into the table variable along with the just initialized level and initial

sort path. The code then defines a loop that keeps iterating as long as the

number of rows affected by the previous insert is nonzero, and we haven’t yet

reached the maximum number of levels if one was specified. In each round,

the loop increments the level counter and inserts the next level of

subordinates into the table variable. Finally, the code executes the RETURN

command, causing the function to exit and hand the table variable to the

calling query.

Use the following code to test the function:

SELECT empid, REPLICATE(‘ | ‘, lvl) + empname AS emp,

mgrid, salary, lvl, sortpath

FROM dbo.GetSubtree(3, NULL) AS T

ORDER BY sortpath;

If you’re wondering why bother implementing a task as a multistatement

function instead of an inline one, there could be a number of reasons. The

recursive query in the inline function uses a spool (worktable) to store the

intermediate results, but you have no control over the indexing on that spool.

With the multistatement function, you control the definition of the table

variable, including indexing. Furthermore, the inline function is only allowed

to return a query, whereas the multistatement function can have complete

flow with procedural logic. It just so happens that the task in our specific

example can be handled with both kinds of functions, so you can try them

both, and compare their performance to see which one works better for you.

But some tasks cannot be handled with a single query, rather require a multistep procedural solution.

### **Stored procedures**

Stored procedures are routines that support flow with multiple steps. They

support many T-SQL elements that user-defined functions don’t, like

modifying data in the database and even applying data definition changes to

database objects (DDL), using temporary tables, dynamic SQL, error

handling, and more. These are clear advantages compared to user-defined

functions; however, unlike with functions, stored procedures cannot be

embedded in queries.

Stored procedures support input and output parameters and can also return

result sets of queries. SQL Server caches the execution plans of the stored

procedure’s queries, and typically reuses them in subsequent executions of

the procedure to save the time, CPU and memory resources that are

associated with optimizing the queries.

Stored procedures provide many benefits compared to implementing the

business logic in the application. They encapsulate the logic to allow

reusability and hiding of complexity. It’s much easier to apply changes to a

stored procedure with a simple ALTER PROC command compared to

deploying changes in the application. Also, with stored procedures you tend

to have less network traffic because when you call a stored procedure from

the application, all that is passed through the network is just the procedure

name and its parameters. The flow runs in the database engine, and then only

the final result is sent to the application. When you implement the logic in the

application, you usually get more roundtrips between the application and the

database, and consequently more network traffic.

Stored procedures also simplify handling security in the database. Often

you don’t want to grant users with permissions to directly query and modify

data in tables, rather you want them to be able to achieve such tasks only

indirectly through stored procedures. To achieve this, grant the users with

EXECUTE permissions on the stored procedure while not granting them

direct access to underlying objects.

#### **Working with stored procedures**

A stored procedure is a reusable routine that supports input and output

parameters, and even returning result sets of queries. This section starts with

a simple example for using input parameters and returning a result set of a

query. I demonstrate using output parameters in a later section.

Suppose that you are given a task to create a stored procedure that handles

what’s called dynamic search conditions to query and filter data from the

Sales.Orders table. The procedure should have four optional input parameters

for filtering the orders by order ID, order date, customer ID, and employee

ID. The executing user determines which combination of columns to filter by.

The way you make the input parameters optional is by defining them with a

default NULL. If the user doesn’t specify a value for an input parameter, it is

set to the default NULL, telling you that you’re not supposed to apply a filter

to the corresponding column.

Run the following code to create the GetOrders stored procedure, which

handles the task at hand:

CREATE OR ALTER PROC dbo.GetOrders

@orderid AS INT = NULL,

@orderdate AS DATE = NULL,

@custid AS INT = NULL,

@empid AS INT = NULL

AS

SET XACT\_ABORT, NOCOUNT ON;

SELECT orderid, orderdate, shippeddate, custid,

empid, shipperid

FROM Sales.Orders

WHERE (orderid = @orderid OR @orderid IS NULL)

AND (orderdate = @orderdate OR @orderdate IS NULL)

AND (custid = @custid OR @custid IS NULL)

AND (empid = @empid OR @empid IS NULL);

GO

Observe the header of the stored procedure with the definition of the input

parameters and the syntax for defining default values. Some people like to

place the parameter definitions within parentheses, as in:

CREATE OR ALTER PROC dbo.GetOrders

( @

orderid AS INT =

NULL,

@orderdate AS DATE = NULL,

@custid AS INT = NULL,

@empid AS INT = NULL

) AS...

As for the body of the stored procedure, notice that there’s no mandatory

BEGIN-END block like in multistatement user-defined functions, but you

can use one if that’s your styling preference, as in:

BEGIN

SET XACT\_ABORT, NOCOUNT ON;

SELECT orderid, orderdate, shippeddate, custid, empid, shipperid

FROM Sales.Orders

WHERE (orderid = @orderid OR @orderid IS NULL)

AND (orderdate = @orderdate OR @orderdate IS NULL)

AND (custid = @custid OR @custid IS NULL)

AND (empid = @empid OR @empid IS NULL);

END;

The stored procedure’s code starts by setting the options XACT\_ABORT

and NOCOUNT to ON. The XACT\_ABORT option determines the effect of

run-time errors raised by T-SQL statements. When this option is OFF (the

default in most cases), some errors cause an open transaction to roll back and

the execution of the code to be aborted, whereas other errors leave the

transaction open. To get a more reliable and consistent behavior, I consider it

a best practice to set this option to ON, and this way all errors cause an open

transaction to be rolled back and the execution of the code to be aborted. The

NOCOUNT option suppresses messages indicating how many rows were

affected by data manipulation statements. When it’s OFF (the default), those

messages can degrade query performance due to the network traffic that they

generate, plus this causes trouble for client applications that perceive those as

query results.

The code then invokes a query against the Sales.Orders table that filters the

data based on the specified parameters. For each parameter the query’s

WHERE clause has the following disjunction of predicates (predicates

separated by an OR operator):

column = @parameter OR @parameter IS NULL

When the user doesn’t specify an input value, the parameter is set to the

default NULL. In such a case the predicate @parameter IS NULL is true, and

therefore the disjunction of predicates is true, so no filtering is applied. When

the user does specify an input value, the predicate @parameter IS NULL is

false, and it is left to the predicate column = @parameter to determine

whether to keep the row or discard it.

Run the following code to test the procedure, asking to filter orders placed

on November 11, 2015 by customer 85:

EXEC dbo.GetOrders @orderdate = ‘20151111’, @custid = 85;

This code generates the following output:

orderid orderdate shippeddate custid empid shipperid

----------- ---------- ----------- ----------- ----------

- -----------

10737 2015-11-11 2015-11-

18 85 2 2

Note that you can also execute the procedure, passing input values without

specifying the target parameter names, but then you need to know the

positions of the parameters in the procedure’s header. Here’s the equivalent

to the above procedure execution passing inputs by position:

EXEC dbo.GetOrders DEFAULT, ‘20151111’, 85, DEFAULT;

Using named parameters is considered a best practice because you need to

specify only the applicable parameters, and you don’t need to know in what

order they are defined in the procedure’s header. The code is also much

clearer.

Execute the procedure again, asking to filter the order with order ID 42:

EXEC dbo.GetOrders @orderid = 42;

Such an order doesn’t exist and therefore the procedure returns an empty

Set

#### **Stored procedures and dynamic SQL**

The previous section demonstrated using a stored procedure to handle a

dynamic search conditions task to query and filter data from the Sales.Orders

table using a static query. This section describes an alternative solution that

uses dynamic SQL, which is a technique that involves building a batch of

code as a character string, usually in a variable, and then telling SQL Server

to execute the code that resides in that variable.

Using a static query in our case is not ideal in terms of query performance.

The reason for this has to do with the fact that SQL Server caches the

execution plan for the query for reuse in subsequent executions of the stored

procedure. The cached plan has to incorporate all filter predicates and not just

the ones that are related to the parameters that are applicable in the execution

that gets optimized. Otherwise, SQL Server would not be able to reuse the

plan in subsequent executions that specify a different set of applicable

parameters. This tends to result in a generalized plan that cannot really be

optimal for all possible combinations of parameters.

One way to get efficient plans is to add the query option RECOMPILE, as

in:

<query> OPTION(RECOMPILE);

With this option, in every execution of the stored procedure SQL Server

optimizes the query from scratch, after applying parameter embedding

(replacing the parameters with constants) and normalizing the query to

remove the redundant parts. For instance, if you execute the procedure,

providing an input value only to the @orderid parameter (say, 10248),

effectively the query that gets optimized is:

SELECT orderid, orderdate, shippeddate, custid, empid,

shipperid

FROM Sales.Orders

WHERE orderid = 10248;

As you can realize, the likelihood to get efficient plans with this solution is

quite high. But this comes at the cost of recompiling the query in every

execution of the stored procedure. If you want to both get optimal plans and

optimal cached query plan reuse behavior, you need to use a different

solution. One of the ways to achieve this is to dynamically build the query

string with only the relevant parameterized predicates, and execute the code

that you built with the sp\_executesql procedure. Here’s the solution code that

implements this approach:

CREATE OR ALTER PROC dbo.bcitsp\_GetOrders

@orderid AS INT = NULL

, @orderdate AS DATE = NULL

, @custid AS INT = NULL

, @empid AS INT = NULL

AS

SET XACT\_ABORT, NOCOUNT ON;

DECLARE @sql AS NVARCHAR(MAX)

SET @sql = N'SELECT orderid, orderdate, shippeddate, custid, empid, shipperid

FROM Sales.Orders

WHERE 1 = 1'

+ CASE WHEN @orderid IS NOT NULL THEN N' AND orderid = @orderid ' ELSE N'' END

+ CASE WHEN @orderdate IS NOT NULL THEN N' AND orderdate = @orderdate' ELSE N'' END

+ CASE WHEN @custid IS NOT NULL THEN N' AND custid = @custid' ELSE N'' END

+ CASE WHEN @empid IS NOT NULL THEN N' AND empid = @empid ' ELSE N'' END

+ N';'

EXEC sys.sp\_executesql

@stmt = @sql

, @params = N'@orderid AS INT, @orderdate AS DATE, @custid AS INT, @empid AS INT'

, @orderid = @orderid

, @orderdate = @orderdate

, @custid = @custid

, @empid = @empid;

GO

The code declares a variable called @sql to store the dynamic query string.

It constructs it with the fixed SELECT and FROM parts first. It starts the

WHERE clause with the predicate 1 = 1, which is always true, to avoid

needing to deal differently with the first applicable element that needs to be

concatenated versus the nonfirst ones. Then, using a CASE expression, for

each applicable parameter (one that is not NULL), the code concatenates a

parameterized predicate to the filter, otherwise an empty string.

The code then executes the dynamically built query by using the

sp\_executesql procedure. The first part of the procedure is the @stmt

parameter, where you provide the string with the code that you want to

execute (@sql variable in our case). The second part is the @params

parameter, where you declare all of the dynamic batch parameters. In our

case, we declare a corresponding dynamic batch parameter for each of the

stored procedure’s parameters. It’s quite all right if you wish to use the same

names for the dynamic batch parameters and the stored procedure’s

parameters as is done in our example. The last part is a series of assignments

of the stored procedure’s parameters to the corresponding dynamic batch

parameters.

Use the following code to test the stored procedure:

EXEC dbo.GetOrders @orderdate = ‘20151111’, @custid = 85;

You get the following output:

orderid orderdate shippeddate custid empid shipperid

----------- ---------- ----------- ----------- ----------

- -----------

10737 2015-11-11 2015-11-

18 85 2 2

Each unique query string (same combination of parameters) that is used

gets optimized separately, and SQL Server is able to reuse a previously

cached plan when the query string matches.

## **Implement error handling and transactions**

Transactions and error handling are two mechanisms in SQL Server that

enable you to work with a consistent database and define the course of action

to take in case of errors. The two are strongly intertwined. When errors

happen in transactions, the default handling of SQL Server is not always the

desired one; with your own error handling, you have some degree of control

over the outcome. This skill starts with coverage of transactions. It then

describes the error handling constructs that T-SQL supports. It then explains

how to handle errors that happen in transactions.

### **Understanding transactions**

A transaction is a unit of work with one or more activities that manipulate

data, and possibly its structure (yes, unlike in some other database platforms,

in SQL Server most DDL is transactional!). A transaction has, or at least

should have, four main properties known collectively as the ACID properties.

A stands for atomicity, C for consistency, I for isolation, and D for durability.

Theoretically, a transaction should be atomic; namely either complete in its

entirety or not take place at all. In practice, this is not always the default

behavior in SQL Server, and in order to achieve true atomicity, you need to

add your own error handling code.

A transaction should be consistent; namely, it should transition the

database from one consistent state to another in terms of adhering to the data

model, constraints, and triggers.

A transaction should be isolated; this means that intermediate inconsistent

states of the data are supposed to be visible only to the transaction that made

the changes, but not to other transactions. You can set what’s called an

isolation level either at the session level with a SET TRANSACTION

ISOLATION LEVEL option, or at the query level with a table hint to control

the degree of isolation that you get.

Finally, a transaction should be durable; this means that when you commit

the transaction and get an acknowledge from the database that the transaction

committed successfully, you can rest assured that the transaction’s changes

are durable. This means that the changes can survive a crash of the SQL

Server process, such as a result of a power failure event.

**Defining transactions**

SQL Server allows you to either explicitly define the transaction’s

boundaries yourself or to let it define those implicitly for you. To explicitly

mark the beginning of a transaction, use the BEGIN TRANSACTION

statement (or BEGIN TRAN for brevity). To end the transaction and commit

its work, use the COMMIT TRANSACTION statement (supported

alternatives: COMMIT TRAN, COMMIT WORK and just COMMIT). To

end a transaction and roll back its work, undoing all of its changes, use the

ROLLBACK TRANSACTION statement (supported alternatives:

ROLLBACK TRAN, ROLLBACK WORK and just ROLLBACK).

You can query a function called @@TRANCOUNT to know whether

you’re currently in an open transaction or not. If you’re in an open

transaction the function returns a value greater than zero, otherwise, it returns

zero. I provide more details about this function later under the topic Nesting

of transactions.

As an example, the following code uses an explicit user transaction to add

a new order to the TSQLV4 sample database:

USE TSQLV4;

SET XACT\_ABORT, NOCOUNT ON;

-- start a new transaction

BEGIN TRAN;

-- declare a variable

DECLARE @neworderid AS INT;

-- insert a new order into the Sales.Orders table

INSERT INTO Sales.Orders

(custid, empid, orderdate, requireddate, shippeddate,

shipperid, freight, shipname, shipaddress, shipcity,

shippostalcode, shipcountry)

VALUES

(1, 1, ‘20170212’, ‘20170301’, ‘20170216’,

1, 10.00, N’Shipper 1’, N’Address AAA’, N’City AAA’,

N’11111’, N’Country AAA’);

-- save the new order id in the variable @neworderid

SET @neworderid = SCOPE\_IDENTITY();

PRINT ‘Added new order header with order ID ‘ +

CAST(@neworderid AS VARCHAR(+ ‘. @@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

--insert order lines for new order into Sales.OrderDetails

INSERT INTO Sales.OrderDetails(orderid, productid,

unitprice, qty, discount)

VALUES(@neworderid, 1, 10.00, 1, 0.000),

(@neworderid, 2, 10.00, 1, 0.000),

(@neworderid, 3, 10.00, 1, 0.000);

PRINT ‘Added order lines to new order. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

-- commit the transaction

COMMIT TRAN;

The examples in this section use ad-hoc batches for simplicity, but in a

later section you will encapsulate the code in a stored procedure. The code

starts by setting the XACT\_ABORT and NOCOUNT options to ON. As a

reminder, when the XACT\_ABORT setting is off (the default), not all runtime

errors cause the transaction to roll back, and execution of the code to

abort. By setting this option to on, you provide a more consistent and

expected behavior from transactions whereby all errors cause the transaction

to roll back and execution of the code to abort. By setting the NOCOUNT

option to ON you request to suppress messages reporting how many rows

were affected by DML statements.

The code uses a single transaction to add both an order header to the

Sales.Orders table, and corresponding order lines to the Sales.OrderDetails

table. After inserting the order header row to Orders, the code saves the order

ID that was just generated by the identity property to a variable, and then uses

the variable when adding the order line rows to OrderDetails.

Remember that because you set the XACT\_ABORT setting to ON, if there

had been a run-time error after any of the INSERT statements, the transaction

would have rolled back in its entirety and execution of the code would have

been aborted. In our case, the transaction completed successfully. If you now

query the Orders and OrderDetails tables, you find the data for the new order,

including both the order header and its corresponding order lines.

Next, run the following code to try adding an order with an invalid order

line where the discount is greater that 1:

SET XACT\_ABORT, NOCOUNT ON;

BEGIN TRAN;

DECLARE @neworderid AS INT;

INSERT INTO Sales.Orders

(custid, empid, orderdate, requireddate, shippeddate,

shipperid, freight, shipname, shipaddress, shipcity,

shippostalcode, shipcountry)

VALUES

(2, 2, ‘20170212’, ‘20170301’, ‘20170216’,

2, 20.00, N’Shipper 2’, N’Address BBB’, N’City BBB’,

N’22222’, N’Country BBB’);

SET @neworderid = SCOPE\_IDENTITY();

PRINT ‘Added new order header with order ID ‘ +

CAST(@neworderid AS VARCHAR(+ ‘. @@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

INSERT INTO Sales.OrderDetails(orderid, productid, unitprice, qty, discount)

VALUES(@neworderid, 1, 20.00, 2, 2.000), -

- CHECK violation since discount > 1

(@neworderid, 2, 20.00, 2, 0.000),

(@neworderid, 3, 20.00, 2, 0.000);

PRINT ‘Added order lines to new order. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

COMMIT TRAN;

The first INSERT statement, which adds the order header row, completes

successfully. However, the second INSERT statement, which attempts to add

the order lines, fails due to a CHECK constraint violation because one of the

order lines has a discount value that is greater than 1. The table has a CHECK

constraint that limits the discount to the range 0 through 1. You can see the

constraints that are defined on the table by running the following code:

EXEC sys.sp\_helpconstraint ‘Sales.OrderDetails’;

Because the XACT\_ABORT setting is turned on, the error causes the

transaction to roll back and execution of the code to abort. The execution of

the code generates the following output:

Added new order header with order ID 11079. @@TRANCOUNT is

1.

Msg 547, Level 16, State 0, Line 86

The INSERT statement conflicted with the CHECK constraint

“CHK\_discount”. The conflict

occurred in database “TSQLV4”, table “Sales.OrderDetails”,

column ‘discount’.

Query both tables looking for the rows that are related to the new order:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

WHERE orderid = 11079;

SELECT orderid, productid, qty

FROM Sales.OrderDetails

WHERE orderid = 11079;

You get empty sets back from both queries:

If you don’t explicitly define the transaction boundaries, SQL Server uses

an autocommit mode where each individual statement is considered a

separate transaction, as if it’s preceded by a BEGIN TRAN statement and

followed by a COMMIT TRAN statement. Note that with most statements,

the individual statement must be atomic, meaning that the single statement

either completes in its entirety or not take place at all. For instance, suppose

that you issue a DELETE statement that deletes 100 rows from a table under

autocommit mode. If the statement fails before completion, say after 17 rows

were deleted, SQL Server undoes the change. Either all 100 rows get deleted,

or none at all.

In our example of adding an order, it’s not a good idea to use the

autocommit mode because under this mode the statements that add the order

header and order lines are treated as two separate transactions. If the first

succeeds and the second fails, you end up with the order header added

without related order lines. The following code demonstrates this:

SET XACT\_ABORT, NOCOUNT ON;

DECLARE @neworderid AS INT;

INSERT INTO Sales.Orders

(custid, empid, orderdate, requireddate, shippeddate,

shipperid, freight, shipname, shipaddress, shipcity,

shippostalcode, shipcountry)

VALUES

(3, 3, ‘20170212’, ‘20170301’, ‘20170216’,

3, 30.00, N’Shipper 3’, N’Address CCC’, N’City CCC’,

N’33333’, N’Country CCC’);

SET @neworderid = SCOPE\_IDENTITY();

PRINT ‘Added new order header with order ID ‘ +

CAST(@neworderid AS VARCHAR(+ ‘. @@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

INSERT INTO Sales.OrderDetails(orderid, productid,

unitprice, qty, discount)

VALUES(@neworderid, 1, 30.00, 3, 2.000), -

- CHECK violation since discount > 1

(@neworderid, 2, 30.00, 3, 0.000),

(@neworderid, 3, 30.00, 3, 0.000);

PRINT ‘Added order lines to new order. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

This code generates the following output:

Added new order header with order ID 11080. @@TRANCOUNT is

0.

Msg 547, Level 16, State 0, Line 126

The INSERT statement conflicted with the CHECK constraint

“CHK\_discount”. The conflict

occurred in database “TSQLV4”, table “Sales.OrderDetails”,

column ‘discount’.

Notice that this time you were not in an open transaction after adding the

order header row. Query the tables to see if any rows related to the new order

survived:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

WHERE orderid = 11080;

SELECT orderid, productid, qty

FROM Sales.OrderDetails

WHERE orderid = 11080;

This code generates the following output:

orderid orderdate custid empid

----------- ---------- ----------- -----------

11080 2017-02-12 3 3

orderid productid qty

----------- ----------- ------

Observe that the order header row exists, but there are no corresponding

order lines. That’s obviously an undesirable outcome, which is why it’s

important to perform both activities in a single transaction and not in two

separate ones.

The SQL standard defines an implicit transactions mode, which is

supposed to be the default mode for working with transactions. Under this

mode, when you issue a transactional statement, if a transaction is not open at

that point, the system is supposed to open an implicit transaction for you.

However, unlike under the default autocommit mode in SQL Server, under

the standard implicit transactions mode you are responsible for explicitly

closing the transaction by either committing it or rolling it back. You enable

the standard implicit transactions mode by setting the session option

IMPLICIT\_TRANSACTIONS to ON, like so (make sure you run this code

for the next demo to work):

SET IMPLICIT\_TRANSACTIONS ON;

Assuming you enabled this option, run the following code to add another

order to the system:

SET XACT\_ABORT, NOCOUNT ON;

DECLARE @neworderid AS INT;

--following statement triggers the opening of a transaction but doesn’t close it

INSERT INTO Sales.Orders

(custid, empid, orderdate, requireddate, shippeddate,

shipperid, freight, shipname, shipaddress, shipcity,

shippostalcode, shipcountry)

VALUES

(4, 4, ‘20170212’, ‘20170301’, ‘20170216’,

1, 40.00, N’Shipper 1’, N’Address AAA’, N’City AAA’,

N’11111’, N’Country AAA’);

SET @neworderid = SCOPE\_IDENTITY();

PRINT ‘Added new order header with order ID ‘ +

CAST(@neworderid AS VARCHAR(+ ‘. @@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

INSERT INTO Sales.OrderDetails(orderid, productid, unitprice, qty, discount)

VALUES(@neworderid, 1, 40.00, 4, 0.000),

(@neworderid, 2, 40.00, 4, 0.000),

(@neworderid, 3, 40.00, 4, 0.000);

PRINT ‘Added order lines to new order. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

-- must explicitly commit the transaction

COMMIT TRAN;

Notice that this time there’s no explicit BEGIN TRAN statement because

you’re relying on the implicit transactions mode, but there is an explicit

COMMIT TRAN statement. This code generates the following output:

Added new order header with order ID 11081. @@TRANCOUNT is

1.

Added order lines to new order. @@TRANCOUNT is 1.

This time both the addition of the order header and the addition of the

order lines ran in a single implicit transaction. If there had been a failure in

any of the statements, the entire transaction would have rolled back. In our

case, the transaction completed successfully. Query the tables to see the data

that was added:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

WHERE orderid = 11081;

SELECT orderid, productid, qty

FROM Sales.OrderDetails

WHERE orderid = 11081;

This code generates the following output:

orderid orderdate custid empid

----------- ---------- ----------- -----------

11081 2017-02-12 4 4

orderid productid qty

----------- ----------- ------

11081 1 4

11081 2 4

11081 3 4

Run the following code to turn the implicit transactions mode back off:

SET IMPLICIT\_TRANSACTIONS OFF;

Having implicit transactions turned on is usually a bad idea. It increases

the likelihood that transactions stay open for long periods, or worse, just stay

open until someone realizes that that’s the case and manually intervenes.

Long open transactions can cause performance problems in the system,

including blocking and others. Also, your code has to be written differently to

work with implicit transactions.

Remember that both DML and DDL are transactional in SQL Server.

However, assignment of values to variables as well as changes to table

variables are not transactional, other than each individual statement having to

complete in its entirety or not take place at all. Run the following code to see

that DDL is transactional:

DROP TABLE IF EXISTS dbo.T1;

BEGIN TRAN;

CREATE TABLE dbo.T1(col1 INT);

INSERT INTO dbo.T1(col1) VALUES(1),(2),(3);

PRINT ‘In transaction’;

SELECT col1 FROM dbo.T1;

ROLLBACK TRAN;

PRINT ‘After transaction’;

SELECT col1 FROM dbo.T1;

This code generates the following output under Results to Text (Ctrl + T):

In transaction

col1

-----------

123

After transaction

Msg 208, Level 16, State 1, Line 206

Invalid object name ‘dbo.T1’.

As you can see, the table creation and population were both undone when

the transaction was rolled back. As a result, the attempt to query the table

after the ROLLBACK TRAN statement was submitted generates an error

because the table doesn’t exist at that point.

Run the following code to see that changes to a table variable are not

undone when a transaction is rolled back:

BEGIN TRAN;

DECLARE @T1 AS TABLE(col1 INT);

INSERT INTO @T1(col1) VALUES(1),(2),(3);

PRINT ‘In transaction’;

SELECT col1 FROM @T1;

ROLLBACK TRAN;

PRINT ‘After transaction’;

SELECT col1 FROM @T1;

This code generates the following output, again, under Results to Text:

**Click here to view code image**

In transaction

col1

-----------

123

After transaction

col1

-----------

123

As you can see, the table variable itself, as well as the data that you

inserted into it, are still present after the transaction was rolled back. As

mentioned, you would get the same behavior when assigning values to

regular variables in a transaction.

**Nesting of transactions**

SQL Server doesn’t support a true concept of nested transactions where

you can have an inner transaction that is completely independent of an outer

one. Rather, in SQL Server you’re either in a transaction or not. When you

issue a BEGIN TRAN statement, SQL Server increases the value of

@@TRANCOUNT in order to know when it needs to truly open a

transaction—when @@TRANCOUNT changes from zero to a greater-than zero

value. Issuing a BEGIN TRAN statement when @@TRANCOUNT is

already greater than zero has no real effect other than increasing the

@@TRANCOUNT value. When you issue a COMMIT TRAN statement

SQL Server decreases the @@TRANCOUNT value by 1. SQL Server truly

commits the transaction only if you issue a COMMIT TRAN statement when

@@TRANCOUNT is 1 prior to committing. However, if you issue a

ROLLBACK TRAN statement in an open transaction, never mind the current

value of @@TRANCOUNT, SQL Server rolls back the entire transaction.

Run the following code to test the behavior of nested BEGIN TRAN

statement:

SET NOCOUNT ON;

DROP TABLE IF EXISTS dbo.T1;

GO

CREATE TABLE dbo.T1(col1 INT);

PRINT ‘@@TRANCOUNT before first BEGIN TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

BEGIN TRAN;

PRINT ‘@@TRANCOUNT after first BEGIN TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

BEGIN TRAN;

PRINT ‘@@TRANCOUNT after second BEGIN TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

BEGIN TRAN;

PRINT ‘@@TRANCOUNT after third BEGIN TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

INSERT INTO dbo.T1 VALUES(1),(2),(3);

COMMIT TRAN; -- this doesn’t really commit

PRINT ‘@@TRANCOUNT after first COMMIT TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

ROLLBACK TRAN; -- this does roll the transaction back

PRINT ‘@@TRANCOUNT after ROLLBACK TRAN is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

SELECT col1 FROM dbo.T1;

This code generates the following output:

@@TRANCOUNT before first BEGIN TRAN is 0.

@@TRANCOUNT after first BEGIN TRAN is 1.

@@TRANCOUNT after second BEGIN TRAN is 2.

@@TRANCOUNT after third BEGIN TRAN is 3.

@@TRANCOUNT after first COMMIT TRAN is 2.

@@TRANCOUNT after ROLLBACK TRAN is 0.

col1

-----------

Observe that every BEGIN TRAN statement increased the

@@TRANCOUNT value by 1, but as soon as the ROLLBACK TRAN

statement was issued, @@TRANCOUNT dropped to 0. Also, observe that

the INSERT statement that added three rows to the table T1 was rolled back

even though you issued a COMMIT TRAN statement after it, because that

statement did not really commit the transaction.

The point in supporting nested BEGIN TRAN-COMMIT TRAN

statements is to allow you to issue those statements within a stored

procedure without needing to check first if a transaction is already

open. If your procedure actually opens the transaction, its COMMIT

TRAN statement is supposed to also actually commit it as well.

However, if a transaction was opened by an outer module or batch, it’s

not supposed to be the inner procedure’s choice to actually commit it,

rather the outer module’s choice. Just make sure to remember that if

you issue a ROLLBACK TRAN statement at any point, even if you do

so from an inner module that was not the one that actually opened the

transaction, this causes the entire transaction to truly roll back and all

of its changes to be undone. The following example demonstrates this.

Normally, you would encapsulate the logic of the previously demonstrated

task of adding an order within a stored procedure. You can pass the order

header info to the stored procedure as scalar input parameters. However,

because the order lines info should be passed as a set, you would probably

want to work with a table valued parameter, or a TVP in short. Before using a

TVP you need to prepare a table type, which is a table definition that you

store as an object in the database and later use as a type for table variables

and TVPs. Run the following code to create the type dbo.OrderLines for this

purpose:

DROP TYPE IF EXISTS dbo.OrderLines;

GO

CREATE TYPE dbo.OrderLines AS TABLE

(

productid INT NOT NULL PRIMARY KEY,

unitprice MONEY NOT NULL CHECK (unitprice >= 0),

qty SMALLINT NOT NULL CHECK (qty > 0),

discount NUMERIC(4, 3) NOT NULL CHECK (discount BETWEEN 0 AND 1)

);

Run the following code to create the stored procedure dbo.AddOrder:

CREATE OR ALTER PROC dbo.AddOrder

@custid AS INT,

@empid AS INT,

@orderdate AS DATE,

@requireddate AS DATE,

@shippeddate AS DATE,

@shipperid AS INT,

@freight AS MONEY,

@shipname AS NVARCHAR(40),

@shipaddress AS NVARCHAR(60),

@shipcity AS NVARCHAR(15),

@shipregion AS NVARCHAR(15),

@shippostalcode AS NVARCHAR(10),

@shipcountry AS NVARCHAR(15),

@OrderLines AS dbo.OrderLines READONLY,

@neworderid AS INT OUT

AS

SET XACT\_ABORT, NOCOUNT ON;

BEGIN TRAN;

-- add order header

INSERT INTO Sales.Orders

(custid, empid, orderdate, requireddate, shippeddate,

shipperid, freight, shipname, shipaddress, shipcity,

shippostalcode, shipcountry)

VALUES

(@custid, @empid, @orderdate, @requireddate, @shippeddate,

@shipperid, @freight, @shipname, @shipaddress, @shipcity,

@shippostalcode, @shipcountry);

SET @neworderid = SCOPE\_IDENTITY();

-- add order lines

INSERT INTO Sales.OrderDetails(orderid, productid,

unitprice, qty, discount)

SELECT @neworderid, productid, unitprice, qty, discount

FROM @OrderLines;

COMMIT TRAN;

The first 13 parameters contain the order header’s attributes. The 14th

parameter is a TVP named @OrderLines and is of the OrderLines table type.

Notice that it has to be marked as READONLY, meaning that you cannot

apply changes to its contents. In our case, it is sufficient as a read-only

parameter. The 15th parameter is an output parameter through which you

return the newly generated order ID to the caller.

The procedure starts by setting XACT\_ABORT and NOCOUNT to ON as

suggested earlier. You want to make sure that if any errors occur, you never

leave the transaction open. The code then performs the addition of the order

header and order lines in an explicit transaction. What’s currently missing is

error handling code, but I take care of this in the section Error handling with

TRY-CATCH.

To execute the stored procedure from T-SQL, you first need to declare a

table variable of the OrderLines table type and populate it with rows. You

then assign the table variable to the TVP when you call the stored procedure.

You also prepare a variable to collect the newly generated order ID from the

output parameter. Here’s an example for executing the stored procedure:

DECLARE @MyOrderLines AS dbo.OrderLines, @myneworderid AS INT;

INSERT INTO @MyOrderLines(productid, unitprice, qty, discount)

VALUES(1, 50.00, 5, 0.000),

(2, 50.00, 5, 0.000),

(3, 50.00, 5, 0.000);

EXEC dbo.AddOrder

@custid = 5,

@empid = 5,

@orderdate = ‘20170212’,

@requireddate = ‘20170301’,

@shippeddate = ‘20170216’,

@shipperid = 2,

@freight = 50.00,

@shipname = N’Shipper 2’,

@shipaddress = N’Address BBB’,

@shipcity = N’City BBB’,

@shipregion = N’Region BBB’,

@shippostalcode = N’22222’,

@shipcountry = N’Country BBB’,

@OrderLines = @MyOrderLines,

@neworderid = @myneworderid OUT;

PRINT ‘Added new order with order ID ‘

+ CAST(@myneworderid AS VARCHAR(10)) + ‘.’;

This code generates the following output:

Added new order with order ID 11082.

Run the following code to query the data for the new order:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

WHERE orderid = 11082;

SELECT orderid, productid, qty

FROM Sales.OrderDetails

WHERE orderid = 11082;

This code generates the following output:

orderid orderdate custid empid

----------- ---------- ----------- -----------

11082 2017-02-12 5 5

orderid productid qty

----------- ----------- ------

11082 1 5

11082 2 5

11082 3 5

Next, run the following code to execute the stored procedure from an

explicit transaction, and then roll the transaction back:

BEGIN TRAN;

DECLARE @MyOrderLines AS dbo.OrderLines, @myneworderid AS INT;

INSERT INTO @MyOrderLines(productid, unitprice, qty, discount)

VALUES(1, 60.00, 6, 0.000),

(2, 60.00, 6, 0.000),

(3, 60.00, 6, 0.000);

EXEC dbo.AddOrder

@custid = 6,

@empid = 6,

@orderdate = ‘20170212’,

@requireddate = ‘20170301’,

@shippeddate = ‘20170216’,

@shipperid = 3,

@freight = 60.00,

@shipname = N’Shipper 3’,

@shipaddress = N’Address CCC’,

@shipcity = N’City CCC’,

@shipregion = N’Region CCC’,

@shippostalcode = N’33333’,

@shipcountry = N’Country CCC’,

@OrderLines = @MyOrderLines,

@neworderid = @myneworderid OUT;

PRINT ‘Added new order with order ID ‘

+ CAST(@myneworderid AS VARCHAR(10)) + ‘.’;

ROLLBACK TRAN;

This code generates the following output:

Added new order with order ID 11083.

The COMMIT TRAN statement within the stored procedure doesn’t truly

commit the transaction because it doesn’t reduce @@TRANCOUNT to zero.

Because the outer batch issues a ROLLBACK TRAN statement, the work

that added the header and lines of order 11083 was undone. Query the tables

to look for the data of the new order:

SELECT orderid, orderdate, custid, empid

FROM Sales.Orders

WHERE orderid = 11083;

SELECT orderid, productid, qty

FROM Sales.OrderDetails

WHERE orderid = 11083;

This code generates the following output:

orderid orderdate custid empid

----------- ---------- ----------- -----------

orderid productid qty

----------- ----------- ------

Note that if you insist on actually committing the transaction in your stored

procedure irrespective of whether you started it or not, you can use a loop

that keeps committing until @@TRANCOUNT drops to zero, like so:

WHILE @@TRANCOUNT > 0

COMMIT TRAN;

This isn’t considered a very good practice because someone who started a

transaction and then called your procedure also expects to be able to control

whether to commit it or roll it back. Also, if there’s a mismatch between the

@@TRANCOUNT values when the procedure starts and when it finishes,

SQL Server generates error 266 indicating the mismatch. Though this error

doesn’t terminate an open transaction and doesn’t abort the execution of the

code even if XACT\_ABORT is set to ON.

To demonstrate this I use a stored procedure called dbo.Proc1 that uses an

explicit transaction to create a table called dbo.DoIExist, with a loop that

keeps committing until @@TRANCOUNT drops to zero. Run the following

code to create the stored procedure:

**Click here to view code image**

CREATE OR ALTER PROC dbo.Proc1

AS

SET XACT\_ABORT, NOCOUNT ON;

BEGIN TRAN;

PRINT ‘In transaction in proc. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

CREATE TABLE dbo.DoIExist(col1 int);

WHILE @@TRANCOUNT > 0

COMMIT TRAN;

PRINT ‘Still in proc. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

GO

Use the following code to test the procedure without first opening a

transaction in the outer batch:

**Click here to view code image**

DROP TABLE IF EXISTS dbo.DoIExist;

EXEC dbo.Proc1;

IF OBJECT\_ID(‘dbo.DoIExist’) IS NOT NULL

PRINT ‘DoIExist exists.’

ELSE

PRINT ‘DoIExist does not exist.’;

PRINT ‘Still in batch. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

This code generates the following output, as expected:

**Click here to view code image**

In transaction in proc. @@TRANCOUNT is 1.

Still in proc. @@TRANCOUNT is 0.

DoIExist exists.

Still in batch. @@TRANCOUNT is 0.

Now execute the stored procedure from an outer transaction that you wish

to roll back:

**Click here to view code image**

DROP TABLE IF EXISTS dbo.DoIExist;

BEGIN TRAN;

EXEC dbo.Proc1;

PRINT ‘Still in batch. @@TRANCOUNT is ‘

+ CAST(@@TRANCOUNT AS VARCHAR(10)) + ‘.’;

IF @@TRANCOUNT > 0

ROLLBACK TRAN;

IF OBJECT\_ID(‘dbo.DoIExist’) IS NOT NULL

PRINT ‘DoIExist exists.’

ELSE

PRINT ‘DoIExist does not exist.’;

This code generates the following output:

**Click here to view code image**

In transaction in proc. @@TRANCOUNT is 2.

Still in proc. @@TRANCOUNT is 0.

Msg 266, Level 16, State 2, Procedure dbo.Proc1, Line 0

[Batch Start Line 436]

Transaction count after EXECUTE indicates a mismatching

number of BEGIN and COMMIT

statements. Previous count = 1, current count = 0.

Still in batch. @@TRANCOUNT is 0.

DoIExist exists.

The stored procedure actually committed the transaction even though it

wasn’t the one that opened it. You get an error indicating the mismatch in the

@@TRANCOUNT values when entering and leaving the procedure, but this

error doesn’t stop the execution of the code and doesn’t cause the transaction

to roll back. The table creation gets committed and the outer batch’s

ROLLBACK TRAN statement doesn’t get the chance to execute.

### **Working with named transactions, savepoints, and markers**

T-SQL supports indicating a name as part of the ROLLBACK

TRAN[SACTION] statement, as in:

ROLLBACK TRAN SomeName;

The name has to have a binary match either with an outermost transaction

name that you assigned earlier with the statement BEGIN TRAN[SACTION]

<name>, or a savepoint name that you assigned earlier with the statement

SAVE TRAN[SACTION] <name>.

The idea behind rolling back to a transaction name is to verify that you’re

explicitly rolling back the outermost transaction. If that’s not the case, you

get an error. As an example, run the following code:

SET XACT\_ABORT OFF;

BEGIN TRAN OutermostTran;

BEGIN TRAN InnerTran1;

BEGIN TRAN InnerTran2;

ROLLBACK TRAN OutermostTran;

PRINT ‘@@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10))

+ ‘.’;

Because there’s a match between the names in the ROLLBACK TRAN

statement and the outermost BEGIN TRAN statement, the outermost

transaction is rolled back successfully. This code generates the following

output:

@@TRANCOUNT is 0.

As another example, run the following code, this time specifying an inner

transaction name in the ROLLBACK TRAN statement:

SET XACT\_ABORT OFF;

BEGIN TRAN OutermostTran;

BEGIN TRAN InnerTran1;

BEGIN TRAN InnerTran2;

ROLLBACK TRAN InnerTran1;

PRINT ‘@@TRANCOUNT is ‘ + CAST(@@TRANCOUNT AS VARCHAR(10))

+ ‘.’;

GO

ROLLBACK TRAN;

The attempt to roll the transaction back fails, the transaction remains open,

and the code continues execution. This code generates the following output:

Msg 6401, Level 16, State 1, Line 472

Cannot roll back InnerTran1. No transaction or savepoint

of that name was found.

@@TRANCOUNT is 3.

Keep in mind, though, that the above examples are executed with

XACT\_ABORT set to OFF, as is the case by default. If you follow best

practices and set this option to ON, in the second example the error—not the

ROLLBACK TRAN statement itself—causes the open transaction to roll

back and the execution of the code to abort.

If you issue a ROLLBACK TRAN statement without a name, it behaves as

usual irrespective of whether you named transactions or not; namely, it rolls

the entire transaction back.

You can also specify a transaction name in the COMMIT

TRAN[SACTION] statement, as in COMMIT TRAN SomeName, but with

this command the name is simply ignored.

Naming transactions is a very uncommonly used practice. This book

covers it mainly for the small chance that it would appear in the exam.

T-SQL also supports a concept called savepoints. A savepoint is a marker

within an open transaction that you can later roll back to, undoing only the

changes that took place since the savepoint, and not the rest of the changes

that took place in the transaction. When you roll back to a save point, the

transaction remains open and the code continues execution. You mark a

savepoint with the statement SAVE TRAN[ACTION] <savepoint name>,

and roll back to a savepoint using the statement ROLLBACK

TRAN[SACTION] <savepoint name>. You must be in an open transaction to

mark a savepoint; otherwise you get an error. You are allowed to mark

multiple savepoints within the same transaction. You can gradually roll back

to different savepoints, but in such a case you have to keep going backwards;

otherwise you get an error. For example, if you marked save points S1, S2,

S3 in this order, you can later first roll back to S3 and afterwards to S1, but

not the other way around.

The following example demonstrates using savepoints:

SET XACT\_ABORT, NOCOUNT ON;

DROP TABLE IF EXISTS dbo.T1;

GO

CREATE TABLE dbo.T1(col1 VARCHAR(10));

GO

BEGIN TRAN;

SAVE TRAN S1;

INSERT INTO dbo.T1(col1) VALUES(‘S1’);

SAVE TRAN S2;

INSERT INTO dbo.T1(col1) VALUES(‘S2’);

SAVE TRAN S3;

INSERT INTO dbo.T1(col1) VALUES(‘S3’);

ROLLBACK TRAN S3;

ROLLBACK TRAN S2;

SAVE TRAN S4;

INSERT INTO dbo.T1(col1) VALUES(‘S4’);

COMMIT TRAN;

SELECT col1 FROM dbo.T1;

GO

DROP TABLE IF EXISTS dbo.T1;

This code generates the following output:

col1

----------

S1

S4

When the code issued the statement ROLLBACK TRAN S3, the changes

that took place between S3 and that statement were undone (the insertion of

the value ‘S3’ to the table). When the code then issued the statement

ROLLBACK TRAN S2, the changes that took place between S2 and S3 were

undone (the insertion of the value ‘S2’ to the table). So, both the insertion of

the value ‘S1’, which happened before S2, and the insertion of the value ‘S4’,

which happened after the last rollback to a savepoint took place, persisted.

The BEGIN TRAN[SACTION] statement also supports an option called

WITH MARK <marker name>, as in BEGIN TRAN MyTran WITH MARK

‘My Mark’. This option defines a marker name in the transaction log. Later

on, if you apply a restore from a log backup, you can specify the option

STOPATMARK <marker name> to recover the changes only until the

indicated marked transaction, inclusive, or STOPBEFOREMARK <marker

name> to exclude the marked transaction.

### **Error handling with TRY-CATCH**

Robust programming solutions always include code to handle errors. You

want to make sure that you control the outcome of both anticipated and

unanticipated errors to the degree that you can. This is true with any kind of

programming, and of course also specifically with T-SQL. In case of an error,

you do not want to leave a database in an inconsistent state. Also, you do not

want an error to result in an unterminated transaction because this causes

concurrency and other problems in the system.

This section describes the error handling tools that T-SQL supports. It

covers the main T-SQL error handling construct—TRY-CATCH, error

functions, generating error messages with THROW and RAISERROR, and

handling errors in transactions.

**The TRY-CATCH construct**

T-SQL uses a classic TRY-CATCH construct to handle errors, similar to

what most programming languages use for error handling. You place your

usual code within the TRY block, and you place any error handling code

within the CATCH block. If there’s no error in the TRY block, the CATCH

block is skipped. If there is an error in the TRY block, control is passed to the

first line of code within the CATCH block.

As the first example for using the TRY-CATCH construct I demonstrate

code that adds a couple of rows to a table called T1. Run the following code

to create the table T1:

SET NOCOUNT ON;

USE TSQLV4;

DROP TABLE IF EXISTS dbo.T1;

GO

CREATE TABLE dbo.T1

(

keycol INT NOT NULL

CONSTRAINT PK\_T1 PRIMARY KEY,

col1 INT NOT NULL

CONSTRAINT CHK\_T1\_col1\_gtzero CHECK(col1 > 0),

col2 VARCHAR(10) NOT NULL

);

The following example demonstrates execution of code with no errors:

BEGIN TRY

INSERT INTO dbo.T1(keycol, col1, col2)

VALUES(1, 10, ‘AAA’);

INSERT INTO dbo.T1(keycol, col1, col2)

VALUES(2, 20, ‘BBB’);

PRINT ‘Got to end of TRY block.’;

END TRY

BEGIN CATCH

PRINT ‘Error occurred. Entering CATCH block. Error

message: ‘ + ERROR\_MESSAGE();

END CATCH;

GO

SELECT keycol, col1, col2

FROM dbo.T1;

-- cleanup

TRUNCATE TABLE dbo.T1;

The code in the TRY block runs successfully and therefore the CATCH

block is skipped. This code generates the following output:

Got to the end of the TRY block.

keycol col1 col2

----------- ----------- ----------

1 10 AAA

2 20 BBB

The following example demonstrates execution of code with an error:

BEGIN TRY

INSERT INTO dbo.T1(keycol, col1, col2)

VALUES(1, 10, ‘AAA’);

INSERT INTO dbo.T1(keycol, col1, col2)

VALUES(2, -20, ‘BBB’);

PRINT ‘Got to the end of the TRY block.’;

END TRY

BEGIN CATCH

PRINT ‘Error occurred. Entering CATCH block. Error

message: ‘ + ERROR\_MESSAGE();

END CATCH;

GO

SELECT keycol, col1, col2

FROM dbo.T1;

-- cleanup

TRUNCATE TABLE dbo.T1;

The first INSERT statement runs successfully and the row makes it to the

table. The second INSERT statement fails due to a CHECK constraint

violation when it tries to add a row with a col1 value that is not greater than

zero. The second row doesn’t make it to the table. The PRINT command at

the end of the TRY block doesn’t get to execute. Control of the code passes

to the CATCH block, which in this example simply prints a message

indicating that an error occurred along with the error message. This code

generates the following output:

Error occurred. Entering CATCH block. Error message: The

INSERT statement conflicted

with the CHECK constraint “CHK\_T1\_col1\_gtzero”. The

conflict occurred in database

“TSQLV4”, table “dbo.T1”, column ‘col1’.

keycol col1 col2

----------- ----------- ----------

1 10 AAA

This is hardly an example for robust error handling because this code

leaves the database in an inconsistent state with only one of the two rows

making it into the target table. Normally you would place the work in a

transaction and make sure that when an error happens you roll the transaction

back, but I get to this later. For now, I just wanted to demonstrate the flow of

the code with the TRY-CATCH construct when it runs successfully and when

there is an error.

If an error happens within a stored procedure and is handled by a TRYCATCH

construct, as far as the caller of the stored procedure is concerned,

there was no error. If an error happens in a stored procedure, but not in a

TRY block, the error bubbles up in the call stack until it finds a TRY block,

and if one is found, it activates the corresponding CATCH block. For

example, say Proc1 calls Proc2 from within a TRY block, and Proc2 runs

code without using a TRY-CATCH construct. An error in Proc2 results in the

CATCH block of Proc1 being activated. If no TRY-CATCH construct is

found along the way, the caller who initiated the code ends up getting the

error.

For cases where code within the CATCH bock can potentially fail, you

are allowed to nest a TRY-CATCH construct within the CATCH

block, and this way handle such errors. If an error happens in a

CATCH block, but not in a nested TRY-CATCH construct, the error

behaves as if it didn’t happen in a TRY block; namely, it bubbles up.

To demonstrate nesting of TRY-CATCH constructs I use a procedure

called AddRowToT1 and a table called ErrorLog where the procedure is

supposed to log errors.

Run the following code to create the table ErrorLog:

DROP TABLE IF EXISTS dbo.ErrorLog;

GO

CREATE TABLE dbo.ErrorLog

(

id INT NOT NULL IDENTITY

CONSTRAINT PK\_ErrorLog PRIMARY KEY,

dt DATETIME2 NOT NULL DEFAULT(SYSDATETIME()),

loginname NVARCHAR(128) NOT NULL DEFAULT(SUSER\_SNAME()),

errormessage NVARCHAR(4000) NOT NULL

);

The table definition uses default constraints to record the time of the error

and the executing login.

Run the following code to create the stored procedure AddRowToT1:

CREATE OR ALTER PROC dbo.AddRowToT1

@keycol INT,

@col1 INT,

@col2 VARCHAR(10)

AS

SET NOCOUNT ON;

BEGIN TRY

INSERT INTO dbo.T1(keycol, col1, col2)

VALUES(@keycol, @col1, @col2);

PRINT ‘Got to the end of the outer TRY block.’;

END TRY

BEGIN CATCH

PRINT ‘Error occurred in outer TRY block. Entering

outer CATCH block.’;

BEGIN TRY

INSERT INTO dbo.ErrorLog(errormessage)

VALUES(ERROR\_MESSAGE());

PRINT ‘Got to the end of the inner TRY block.’;

END TRY

BEGIN CATCH

PRINT ‘Error occurred in inner TRY block. Entering

inner CATCH block. END CATCH;

END CATCH;

GO

As you can see, the stored procedure uses an outer TRY block to add a row

to T1 with the values received as input parameters. If all goes well, the outer

TRY block prints a message indicating that it got to the end. Note that the

PRINT statements are used here only for illustration purposes to show which

parts of the code got executed; normally, you would not include those in

production code. In case of an error, the outer CATCH block is activated.

The code in the outer CATCH block prints that it got there, and then activates

an inner TRY-CATCH construct. The inner TRY block tries to write the error

information into the table ErrorLog. If all goes well, the code indicates that it

got to the end of the inner TRY block. If there’s an error in the inner TRY

block, the inner CATCH block is activated. The inner CATCH block prints a

message indicating the code got there and the error message.

Use the following code to test the procedure for the first time:

EXEC dbo.AddRowToT1

@keycol = 1,

@col1 = 10,

@col2 = ‘AAA’;

GO

SELECT keycol, col1, col2 FROM dbo.T1;

SELECT id, dt, loginname, errormessage FROM dbo.ErrorLog;

-- cleanup

TRUNCATE TABLE dbo.T1;

TRUNCATE TABLE dbo.ErrorLog;

The code runs successfully with no errors. The code generates the

following output:

Got to the end of the outer TRY block.

keycol col1 col2

----------- ----------- ----------

1 10 AAA

id dt loginname errormessage

---- --- ---------- -------------

As you can see, the outer TRY block executed to completion. The code

added a new row into the table T1. The outer CATCH block was skipped,

and no row was added to the table ErrorLog.

Run the following code in attempt to add a row with an invalid col1 value:

EXEC dbo.AddRowToT1

@keycol = 1,

@col1 = -10,

@col2 = ‘BBB’;

GO

SELECT keycol, col1, col2 FROM dbo.T1;

SELECT id, dt, loginname, errormessage FROM dbo.ErrorLog;

-- cleanup

TRUNCATE TABLE dbo.T1;

TRUNCATE TABLE dbo.ErrorLog;

This time there’s an error when the outer TRY block attempts to add the

row into T1, therefore the outer CATCH block is activated. The outer

CATCH block uses an inner TRY-CATCH construct to add a row with the

error information into the table ErrorLog. The inner TRY block succeeds in

this task and therefore the inner CATCH block is skipped. This code

generates the following output (formatted for clarity):

Error occurred in outer TRY block. Entering outer CATCH block.

Got to the end of the inner TRY block.

keycol col1 col2

----------- ----------- ----------

id dt loginname

----------- --------------------------- -------------

1 2017-01-24 09:44:24.1014963 <your\_login>

errormessage

----------------------------------------------------------

----------------------------------------------------------

---------------------------------------

The INSERT statement conflicted with the CHECK constraint “CHK\_T1\_col1\_occurred in database “TSQLV4”, table “dbo.T1”, column ‘col1’.

The new row didn’t make it into T1. A row with the error info was written

into ErrorLog.

To test an example for an error in the inner CATCH block, open two new

connections (I refer to them as connection 1 and connection 2). Run the

following code in connection 1 to obtain an exclusive table lock on the table

ErrorLog within a transaction that the code leaves open:

BEGIN TRAN;

SELECT TOP (0) \* FROM dbo.ErrorLog WITH (TABLOCKX);

Next, run the following code to first set the session’s lock expiration time

out to zero (no wait), and then to attempt to add an invalid row:

SET LOCK\_TIMEOUT 0;

EXEC dbo.AddRowToT1

@keycol = 1,

@col1 = -10,

@col2 = ‘BBB’;

The outer TRY block fails when trying to add the invalid row, activating

the outer CATCH block. The outer CATCH block activates the inner TRYCATCH

construct. The inner TRY block fails when trying to add a row to the

table ErrorLog because it cannot obtain a lock. Because you set the lock

expiration time out to zero, the inner CATCH block is immediately activated,

printing the inner error information. This code generates the following

output:

Error occurred in outer TRY block. Entering outer CATCH

block.

Error occurred in inner TRY block. Entering inner CATCH

block. Error message:

Lock request time out period exceeded.

Run the following code in connection 1 to commit the open transaction and

release the lock on ErrorLog:

COMMIT TRAN;

Run the following code in connection 2 to query the tables, clean them up,

and to set the lock expiration time out back to infinity:

SELECT keycol, col1, col2 FROM dbo.T1;

SELECT id, dt, loginname, errormessage FROM dbo.ErrorLog;

-- cleanup

TRUNCATE TABLE dbo.T1;

TRUNCATE TABLE dbo.ErrorLog;

SET LOCK\_TIMEOUT -1;

This code generates the following output showing that both tables are

empty:

keycol col1 col2

----------- ----------- ----------

id dt loginname errormessage

---- --- ---------- -------------

Close connection 2 and return to connection 1 before continuing.

An important limitation of TRY-CATCH that you want to make sure that

you’re aware of, and that you plan for, is that it cannot catch compilation

errors, such as referring to objects and columns that don’t exist, in the same

scope. However, you can catch such errors in an outer scope.

As an example, consider the following stored procedure called InnerProc:

CREATE OR ALTER PROC dbo.InnerProc

AS

BEGIN TRY

SELECT nosuchcolumn FROM dbo.NoSuchTable;

END TRY

BEGIN CATCH

PRINT ‘In CATCH block of InnerProc.’;

END CATCH;

GO

The procedure tries to query a table that doesn’t exist.

Run the following code to execute InnerProc:

EXEC dbo.InnerProc;

Because the error is a compilation error, it isn’t caught by the inner

CATCH block. This execution generates the following error:

Msg 208, Level 16, State 1, Procedure dbo.InnerProc, Line

5 [Batch Start Line 703]

Invalid object name ‘dbo.NoSuchTable’.

Use the following code to create a stored procedure called OuterProc that

invokes InnerProc within a TRY block:

CREATE OR ALTER PROC dbo.OuterProc

AS

BEGIN TRY

EXEC dbo.InnerProc;

END TRY

BEGIN CATCH

PRINT ‘In CATCH block of OuterProc.’;

END CATCH;

GO

Use the following code to test OuterProc:

EXEC dbo.OuterProc;

This time the CATCH block of OuterProc is activated, and the execution

generates the following output:

In CATCH block of OuterProc.