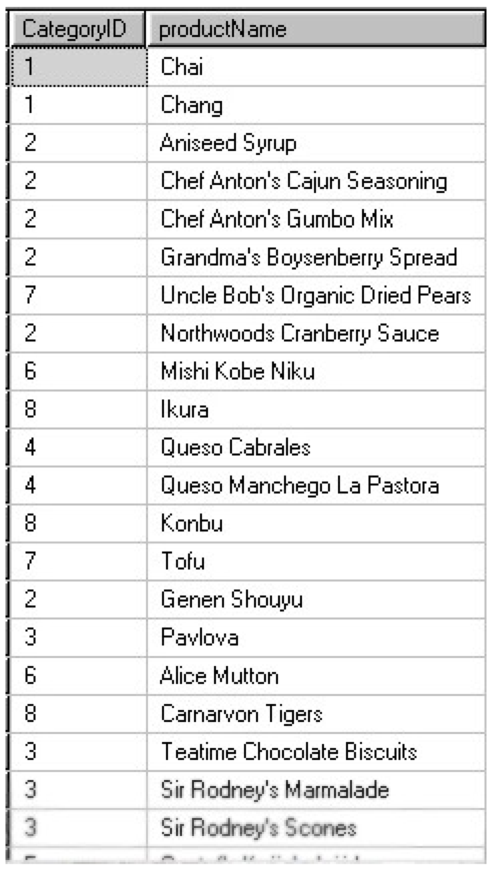
Concatenating Row Values in Transact-SQL - Simple Talk

It is an interesting problem in Transact SQL, for which there are a number of solutions and considerable debate. How do you go about producing a summary result in which a distinguishing column from each row in each particular category is listed in a 'aggregate' column? A simple, and intuitive way of displaying data is surprisingly difficult to achieve. Anith Sen gives a summary of different ways, and offers words of caution over the one you choose.

Introduction

Many a time, SQL programmers are faced with a requirement to generate report-like resultsets directly from a Transact SQL query. In most cases, the requirement arises from the fact that there neither sufficient tools nor in-house expertise to develop tools that can extract the data as a resultset, and then massage the data in the desired display format. Quite often folks are confused about the potential of breaking relational fundamentals such as the First Normal Form or the scalar nature of typed values. (Talking about 1NF violations in a language like SQL which lacks sufficient domain support, allows **NULL**s and supports duplicates is somewhat ironic to begin with, but that is a topic which requires detailed explanations.)



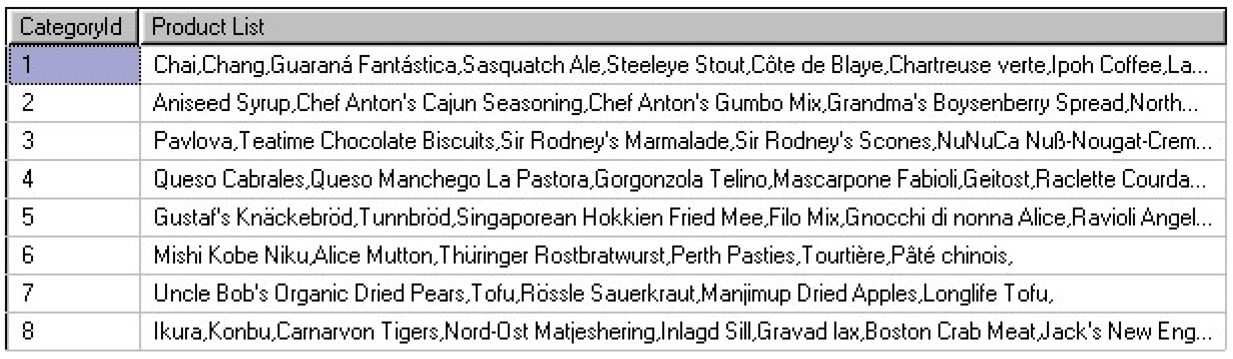
CategoryID	productName
1	Chai
1	Chang
2	Aniseed Syrup
2	Chef Anton's Cajun Seasoning
2	Chef Anton's Gumbo Mix
2	Grandma's Boysenberry Spread
7	Uncle Bob's Organic Dried Pears
2	Northwoods Cranberry Sauce
6	Mishi Kobe Niku
8	Ikura
4	Queso Cabrales
4	Queso Manchego La Pastora
8	Konbu
7	Tofu
2	Genen Shouyu
3	Pavlova
6	Alice Mutton
8	Carnarvon Tigers
3	Teatime Chocolate Biscuits
3	Sir Rodney's Marmalade
3	Sir Rodney's Scones

By ‘Concatenating row values’ we mean this:
You have a table, view or result that looks like this…
…and you wish to have a resultset like the one below:

In this example we are accessing the sample NorthWind database and using the following SQL

```
SELECT CategoryId, ProductName
    FROM Northwind..Products
```

The objective is to return a resultset with two columns, one with the Category Identifier, and the other with a concatenated list of all the Product Names separated by a delimiting character: such as a comma.



CategoryId	Product List
1	Chai,Chang,Guaraná Fantástica,Sasquatch Ale,Steeleye Stout,Côte de Blaye,Chartreuse verte,Ipoh Coffee,La...
2	Aniseed Syrup,Chef Anton's Cajun Seasoning,Chef Anton's Gumbo Mix,Grandma's Boysenberry Spread,North...
3	Pavlova,Teatime Chocolate Biscuits,Sir Rodney's Marmalade,Sir Rodney's Scones,NuNuCa Nuß-Nougat-Crem...
4	Queso Cabrales,Queso Manchego La Pastora,Gorgonzola Telino,Mascarpone Fabioli,Geitost,Raclette Courda...
5	Gustaf's Knäckebröd,Tunnbröd,Singaporean Hokkien Fried Mee,Filo Mix,Gnocchi di nonna Alice,Ravioli Angel...
6	Mishi Kobe Niku,Alice Mutton,Thüringer Rostbratwurst,Perth Pasties,Tourtière,Pâté chinois,
7	Uncle Bob's Organic Dried Pears,Tofu,Rössle Sauerkraut,Manjimup Dried Apples,Longlife Tofu,
8	Ikura,Konbu,Carnarvon Tigers,Nord-Ost Matjeshering,Inlagd Sill,Gravad lax,Boston Crab Meat,Jack's New Eng...

Concatenating column values or expressions from multiple rows are usually best done in a client side application language, since the string manipulation capabilities of Transact SQL and SQL based DBMSs are somewhat limited. However, you can do these using different approaches in Transact SQL, but it is best to avoid such methods in long-term solutions

A core issue

Even though SQL, in general, deviates considerably from the relational model, its reliance on certain core aspects of relational foundations makes SQL functional and powerful. One such core aspect is the set based nature of SQL expressions (well, multi-sets to be exact, but for the given context let us ignore the issue of duplication). The primary idea is that tables are unordered and therefore the resultsets of any query that does not have an explicit **ORDER BY** clause is unordered as well. In other words, the rows in a resultset of a query do not have a prescribed position, unless it is explicitly specified in the query expression.

On the other hand, a concatenated list is an ordered structure. Each element in the list has a specific position. In fact, concatenation itself is an order-utilizing operation in the sense that values can be prefixed or post fixed to an existing list. So approaches that are loosely called “concatenating row values”, “aggregate concatenation" etc. would have to make sure that some kind of an order, either explicit or implicit, should be specified prior to concatenating the row values. If such an ordering criteria is not provided, the concatenated string would be arbitrary in nature.

Considerations

Generally, requests for row value concatenations often comes in two basic flavors, when the number of rows is known and small (typically less than 10) and when the number of rows is unknown and potentially large. It may be better to look at each of them separately.

In some cases, all the programmer wants is just the list of values from a set of rows. There is no grouping or logical partitioning of values such as the list of email addresses separated by a semicolon or some such. In such situations, the approaches can be the same except that the join conditions may vary. Minor variations of the examples list on this page illustrate such solutions as well.

For the purpose of this article the Products table from Northwind database is used to illustrate column value concatenations with a grouping column. Northwind is a sample database in SQL Server 2000 default installations. You can download a copy from from the Microsoft Downloads

Concatenating values when the number of items is small and known beforehand

When the number of rows is small and almost known beforehand, it is easier to generate the code. One common approach where there is a small set of finite rows is the pivoting method. Here is an example where only the first four alphabetically-sorted product names per **categoryid** is retrieved:

```
 SELECT CategoryId,
        MAX( CASE seq WHEN 1 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 2 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 3 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 4 THEN ProductName ELSE '' END )
   FROM ( SELECT p1.CategoryId, p1.ProductName,
                 ( SELECT COUNT(*)
                     FROM Northwind.dbo.Products p2
                     WHERE p2.CategoryId = p1.CategoryId
                     AND p2.ProductName <= p1.ProductName )
          FROM Northwind.dbo.Products p1 ) D ( CategoryId, ProductName, seq )
  GROUP BY CategoryId ;
```

The idea here is to create a expression inside the correlated subquery that produces a rank (**seq**) based on the product names and then use it in the outer query. Using common table expressions and the **ROW_NUMBER()** function, you can re-write this as:

```
; WITH CTE ( CategoryId, ProductName, seq )
  AS ( SELECT p1.CategoryId, p1.ProductName,
         ROW_NUMBER() OVER ( PARTITION BY CategoryId ORDER BY ProductName )
        FROM Northwind.dbo.Products p1 )
SELECT CategoryId,
        MAX( CASE seq WHEN 1 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 2 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 3 THEN ProductName ELSE '' END ) + ', ' +
        MAX( CASE seq WHEN 4 THEN ProductName ELSE '' END )
  FROM CTE
  GROUP BY CategoryId ;
```

Note that **ROW_NUMBER()** is a newly-introduced feature in SQL 2005. If you are using any previous version, you will have to use the subquery approach (You can also use a self-join, to write it a bit differently). Using the recently introduced **PIVOT** operator, you can write this as follows:

```
SELECT CategoryId,
        "1" + ', ' + "2" + ', ' + "3" + ', ' + "4" AS Product_List
   FROM ( SELECT CategoryId, ProductName,
                 ROW_NUMBER() OVER (PARTITION BY CategoryId
             ORDER BY ProductName)
              FROM Northwind.dbo.Products ) P ( CategoryId, ProductName, seq )
  PIVOT ( MAX( ProductName ) FOR seq IN ( "1", "2", "3", "4" ) ) AS P_ ;
```

Not only does the syntax appear a bit confusing, but also it does not seem to offer any more functionality than the previous **CASE** approach. However, in rare situations, it could come in handy.

Concatenating values when the number of items is not known

When you do not know the number of items that are to be concatenated beforehand, the code can become rather more demanding. The new features in SQL 2005 make some of the approaches easier. For instance, the recursive common table expressions (CTEs) and the **FOR XML PATH('')** syntax makes the server do the hard work behind the concatenation, leaving the programmer to deal with the presentation issues. The examples below make this point obvious.

Recursive CTE methods

The idea behind this method is from a newsgroup posting by Vadim Tropashko. It is similar to the ideas behind generating a materialized path for hierarchies.

```
WITH CTE ( CategoryId, product_list, product_name, length )
          AS ( SELECT CategoryId, CAST( '' AS VARCHAR(8000) ), CAST( '' AS VARCHAR(8000) ), 0
                 FROM Northwind..Products
                GROUP BY CategoryId
                UNION ALL
               SELECT p.CategoryId, CAST( product_list +
                      CASE WHEN length = 0 THEN '' ELSE ', ' END + ProductName AS VARCHAR(8000) ),
                      CAST( ProductName AS VARCHAR(8000)), length + 1
                 FROM CTE c
                INNER JOIN Northwind..Products p
                   ON c.CategoryId = p.CategoryId
                WHERE p.ProductName > c.product_name )
SELECT CategoryId, product_list
      FROM ( SELECT CategoryId, product_list,
                    RANK() OVER ( PARTITION BY CategoryId ORDER BY length DESC )
               FROM CTE ) D ( CategoryId, product_list, rank )
     WHERE rank = 1 ;
```

The **CASE** in the recursive part of the CTE is used to eliminate the initial comma, but you can use **RIGHT** or the **SUBSTRING** functions instead. This may not be the best performing option, but certain additional tuning could be done to make them suitable for medium sized datasets.

Another approach using recursive common table expressions was sent in by Anub Philip, an Engineer from Sathyam Computers that uses separate common table expressions for the anchor and recursive parts.

```
WITH Ranked ( CategoryId, rnk, ProductName )
             AS ( SELECT CategoryId,
                         ROW_NUMBER() OVER( PARTITION BY CategoryId ORDER BY CategoryId ),
                         CAST( ProductName AS VARCHAR(8000) )
                    FROM Northwind..Products),
   AnchorRanked ( CategoryId, rnk, ProductName )
             AS ( SELECT CategoryId, rnk, ProductName
                    FROM Ranked
                   WHERE rnk = 1 ),
RecurRanked ( CategoryId, rnk, ProductName )
             AS ( SELECT CategoryId, rnk, ProductName
                    FROM AnchorRanked
                   UNION ALL
                  SELECT Ranked.CategoryId, Ranked.rnk,
                         RecurRanked.ProductName + ', ' + Ranked.ProductName
                    FROM Ranked
                   INNER JOIN RecurRanked
                      ON Ranked.CategoryId = RecurRanked.CategoryId
                     AND Ranked.rnk = RecurRanked.rnk + 1 )
SELECT CategoryId, MAX( ProductName )
      FROM RecurRanked
  GROUP BY CategoryId;
```

On first glance, this query may seem a bit expensive in comparison, but the reader is encouraged to check the execution plans and make any additional tweaks as needed.

The blackbox XML methods

Here is a technique for string concatenation that uses the **FOR XML** clause with **PATH** mode. It was initially posted by Eugene Kogan, and later became common in public newsgroups.

```
SELECT p1.CategoryId,
       ( SELECT ProductName + ','
           FROM Northwind.dbo.Products p2
          WHERE p2.CategoryId = p1.CategoryId
          ORDER BY ProductName
            FOR XML PATH('') ) AS Products
      FROM Northwind.dbo.Products p1
      GROUP BY CategoryId ;
```

There is a similar approach that was originally found in the beta newsgroups, using the **CROSS APPLY** operator.

```
SELECT DISTINCT CategoryId, ProductNames
    FROM Northwind.dbo.Products p1
```

```
   CROSS APPLY ( SELECT ProductName + ','
                 FROM Northwind.dbo.Products p2
                 WHERE p2.CategoryId = p1.CategoryId
                 ORDER BY ProductName
                 FOR XML PATH('') )  D ( ProductNames )
```

You may notice a comma at the end of the concatenated string, which you can remove using a **STUFF, SUBSTRING** or **LEFT** function. While the above methods are deemed reliable by many at the time of writing, there is no guarantee that it will stay that way, given that the internal workings and evaluation rules of **FOR XML PATH()** expression in correlated subqueries are not well documented.

The problem with this approach is that the contents of the ProductName column is interpreted a XML rather than text, which will lead to certain characters being 'entitized', or in some cases, leading to the SQL causing an error. (see note below, and solution by Adam Machanic in comments below) and to avoid this, it is better to use a slightly revised syntax like this..

```
SELECT p1.CategoryId,
       stuff( (SELECT ','+ProductName
               FROM Northwind.dbo.Products p2
               WHERE p2.CategoryId = p1.CategoryId
               ORDER BY ProductName
               FOR XML PATH(''), TYPE).value('.', 'varchar(max)')
            ,1,1,'')
       AS Products
      FROM Northwind.dbo.Products p1
      GROUP BY CategoryId ;
SELECT DISTINCT CategoryId, ProductNames
    FROM Northwind.dbo.Products p1
   CROSS APPLY ( SELECT
       stuff( (SELECT ','+ProductName
               FROM Northwind.dbo.Products p2
               WHERE p2.CategoryId = p1.CategoryId
               ORDER BY ProductName
               FOR XML PATH(''), TYPE).value('.', 'varchar(max)')
            ,1,1,'')
    )  D ( ProductNames )
```

Using Common Language Runtime

Though this article is about approaches using Transact SQL, this section is included due to the popularity of CLR aggregates in SQL 2005. It not only empowers the CLR programmer with new options for database development, but also, in some cases, they work at least as well as native Transact SQL approaches.

If you are familiar with .NET languages, SQL 2005 offers a convenient way to create user defined aggregate functions using C#, VB.NET or similar languages that are supported by the Common Language Runtime (CLR). Here is an example of a string concatenate aggregate function written using C#.

```
using System;
using System.Collections.Generic;
using System.Data.SqlTypes;
using System.IO;
using Microsoft.SqlServer.Server;
[Serializable]
[SqlUserDefinedAggregate(Format.UserDefined,  MaxByteSize=8000)]
public struct strconcat : IBinarySerialize{
        private List values;
        public void Init()    {
            this.values = new List();
        }
        public void Accumulate(SqlString value)    {
            this.values.Add(value.Value);
        }
        public void Merge(strconcat value)    {
            this.values.AddRange(value.values.ToArray());
        }
        public SqlString Terminate()    {
            return new SqlString(string.Join(", ", this.values.ToArray()));
        }
        public void Read(BinaryReader r)    {
            int itemCount = r.ReadInt32();
            this.values = new List(itemCount);
            for (int i = 0; i <= itemCount - 1; i++)    {
```

```
            this.values.Add(r.ReadString());
        }
    }
    public void Write(BinaryWriter w)    {
        w.Write(this.values.Count);
        foreach (string s in this.values)      {
            w.Write(s);
        }
    }
}
```

Once you build and deploy this assembly on the server, you should be able to execute your concatenation query as:

```
SELECT CategoryId,
           dbo.strconcat(ProductName)
      FROM Products
     GROUP BY CategoryId ;
```

If you are a total newbie on CLR languages, and would like to learn more about developing database solutions using CLR languages, consider starting at [Introduction to Common Language Runtime (CLR) Integration]

Scalar UDF with recursion

Recursive functions in t-SQL have a drawback that the maximum nesting level is 32. So this approach is applicable only for smaller datasets, especially when the number of items within a group, that needs to be concatenated, is less than 32.

```
CREATE FUNCTION udf_recursive ( @cid INT, @i INT )
RETURNS VARCHAR(8000) AS BEGIN
        DECLARE @r VARCHAR(8000), @l VARCHAR(8000)
        SELECT @i = @i - 1,  @r = ProductName + ', '
          FROM Northwind..Products p1
         WHERE CategoryId = @cid
           AND @i = ( SELECT COUNT(*) FROM Northwind..Products p2
                        WHERE p2.CategoryId = p1.CategoryId
                          AND p2.ProductName <= p1.ProductName ) ;
        IF @i > 0 BEGIN
              EXEC @l = dbo.udf_recursive @cid, @i ;
              SET @r =  @l + @r ;
END
RETURN @r ;
END
```

This function can be invoked as follows:

```
SELECT CategoryId,
           dbo.udf_recursive( CategoryId, COUNT(ProductName) )
      FROM Northwind..Products
     GROUP BY CategoryId ;
```

Table valued UDF with a WHILE loop

This approach is based on the idea by Linda Wierzbecki where a table variable with three columns is used within a table-valued UDF. The first column represents the group, second represents the currently processing value within a group and the third represents the concatenated list of values.

```
CREATE FUNCTION udf_tbl_Concat() RETURNS @t TABLE(
            CategoryId INT,
            Product VARCHAR(40),
            list VARCHAR(8000) )
BEGIN
     INSERT @t (CategoryId, Product, list)
     SELECT CategoryId, MIN(ProductName),  MIN(ProductName)
       FROM Products
      GROUP BY CategoryId
WHILE ( SELECT COUNT(Product) FROM @t ) > 0 BEGIN
        UPDATE t
           SET list = list + COALESCE(
                         ( SELECT ', ' + MIN( ProductName )
                             FROM Northwind..Products
                            WHERE Products.CategoryId = t.CategoryId
                              AND Products.ProductName > t.Product), ''),
               Product = ( SELECT MIN(ProductName)
                      FROM Northwind..Products
                     WHERE Products.CategoryId = t.CategoryId
                      AND Products.ProductName > t.Product )
     FROM @t t END
RETURN
END
```

The usage of the above function can be like:

```
SELECT CategoryId, list AS Products
  FROM udf_tbl_Concat() ;
```

Dynamic SQL

This approach is a variation of the kludge often known using the nickname of 'dynamic cross tabulation'. There is enough literature out there which demonstrates the drawbacks and implications of using Dynamic SQL. A popular one, at least from Transact SQL programmer's perspective, is Erland's Curse and Blessings of Dynamic SQL. The Dynamic SQL approaches can be developed based on creating a Transact SQL query string based on the number of groups and then use a series of CASE expressions or ROW_NUMBER() function to pivot the data for concatenation.

```
DECLARE @r VARCHAR(MAX), @n INT, @i INT
SELECT @i = 1,
       @r = 'SELECT CategoryId, ' + CHAR(13),
       @n = (SELECT TOP 1 COUNT( ProductName )
              FROM Northwind..Products
             GROUP BY CategoryId
             ORDER BY COUNT( ProductName ) DESC ) ;
WHILE @i <= @n BEGIN
      SET @r = @r +
      CASE WHEN @i = 1
          THEN 'MAX( CASE Seq WHEN ' + CAST( @i AS VARCHAR ) + '
                   THEN ProductName
                        ELSE SPACE(0) END ) + ' + CHAR(13)
      WHEN @i = @n
        THEN 'MAX( CASE Seq WHEN ' + CAST( @i AS VARCHAR ) + '
                   THEN '', '' + ProductName
                   ELSE SPACE(0) END ) ' + CHAR(13)
        ELSE 'MAX( CASE Seq WHEN ' + CAST( @i AS VARCHAR ) + '
                   THEN '', '' + ProductName
                   ELSE SPACE(0) END ) + ' + CHAR(13)
      END ;
      SET @i = @i + 1 ;
END
SET @r = @r + '
    FROM ( SELECT CategoryId, ProductName,
             ROW_NUMBER() OVER ( PARTITION BY CategoryId ORDER BY ProductName )
        FROM Northwind..Products p ) D ( CategoryId, ProductName, Seq )
      GROUP BY CategoryId;'
EXEC( @r ) ;
```

The Cursor approach

The drawbacks of rampant usage of cursors are well-known among the Transact SQL community. Because they are generally resource intensive, procedural and inefficient, one should strive to avoid cursors or loop based solutions in general Transact SQL programming.

```
DECLARE @tbl TABLE (id INT PRIMARY KEY, list VARCHAR(8000))
SET NOCOUNT ON
DECLARE @c INT, @p VARCHAR(8000), @cNext INT, @pNext VARCHAR(40)
DECLARE c CURSOR FOR
        SELECT CategoryId, ProductName
          FROM Northwind..Products
         ORDER BY CategoryId, ProductName ;
        OPEN c ;
        FETCH NEXT FROM c INTO @cNext, @pNext ;
        SET @c = @cNext ;
        WHILE @@FETCH_STATUS = 0 BEGIN
             IF @cNext > @c BEGIN
                  INSERT @tbl SELECT @c, @p ;
                  SELECT @p = @PNext, @c = @cNext ;
        END ELSE
            SET @p = COALESCE(@p + ',', SPACE(0)) + @pNext ;
        FETCH NEXT FROM c INTO @cNext, @pNext
    END
    INSERT @tbl SELECT @c, @p ;
    CLOSE c ;
DEALLOCATE c ;
SELECT * FROM @tbl ;
```

Unreliable approaches

This section details a couple of notorious methods often publicized by some in public forums. The problem with these methods is that they rely on the physical implementation model; changes in indexes, statistics etc or even a change of a simple expression in the SELECT list or ORDER BY clause can change the output. Also these are undocumented, unsupported and unreliable to the point where one can consistently demonstrate failures. Therefore these methods are not recommended at all for production mode systems.

Scalar UDF with t-SQL update extension

It is rare for the usage of an expression that involves a column, a variable and an expression in the SET clause in an UPDATE statement to appear intuitive. However, in general, the optimizer often seems to process these values in the order of materialization, either in the internal work tables or any other storage structures.

```
CREATE FUNCTION udf_update_concat (@CategoryId INT)
    RETURNS VARCHAR(MAX) AS
BEGIN
DECLARE @t TABLE(p VARCHAR(40));
DECLARE @r VARCHAR(MAX) ;
    SET @r = SPACE(0) ;
    INSERT @t ( p ) SELECT ProductName FROM Northwind..Products
                WHERE CategoryId = @CategoryId ;
    IF @@ROWCOUNT > 0
        UPDATE @t
           SET @r = @r + p + ',' ;
    RETURN(@r)
END
```

Here is how to use this function:

```
SELECT CategoryId, dbo.udf_update_concat(CategoryId)
   FROM Northwind..Products
  GROUP BY CategoryId ;
```

Again, it is important to consider that lack of physical independence that is being exploited here before using or recommending this as a usable and meaningful solution.

Scalar UDF with variable concatenation in SELECT

This is an approach purely dependent on the physical implementation and internal access paths. Before using this approach, make sure to refer to the relevant knowledgebase article.

```
CREATE FUNCTION dbo.udf_select_concat ( @c INT )
RETURNS VARCHAR(MAX) AS BEGIN
DECLARE @p VARCHAR(MAX) ;
     SET @p = '' ;
    SELECT @p = @p + ProductName + ','
      FROM Northwind..Products
     WHERE CategoryId = @c ;
RETURN @p
END
```

And, as for its usage:

```
SELECT CategoryId, dbo.udf_select_concat( CategoryId )
   FROM Northwind..Products
  GROUP BY CategoryId ;
```

Conclusion

Regardless of how it is used, “aggregate concatenation” of row values in Transact SQL, especially when there is a grouping, is not a simple routine. You need to consider carefully the circumstances before you choose one method over another. The most logical choice would to have a built-in operator with optional configurable parameters that can do the concatenation of the values depending on the type. Till then, reporting requirements and external data export routines will have to rely on such Transact SQL programming hacks.

Acknowledgements

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Additional information about the XML Blackbox approach inserted 22/03/2012.