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Pentaho Analyzer Cookbook: Calculations and Multidimensional Expressions (MDX)

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Contents

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Overview

This Analyzer Cookbook was written to assist busy people with solving various analysis use cases encountered in real life customer scenarios. Most of these examples in this document came from requests from pre-sales, engineering service requests (ESRs), and talking to customers.

These examples focus on calculations and making use of the power of multidimensional expressions (MDX). Analyzer was built on top of Online Analytical Processing (OLAP) technology, and you can use those capabilities rather than just using operational reporting technology and relational structured query language (SQL).

Because all examples in this book work on the vanilla `SteelWheels` catalog (unless otherwise noted), they should be very easy to replicate and study.

The cookbook is divided up into three sections:

- Core Recipes: Items that we recommend you read through, because they come in handy for most analysis scenarios.
- Basic Recipes: Use cases that Analyzer supports out of the box with no MDX experience needed.
- Advanced Recipes: Use cases that require you to understand how MDX expressions are evaluated.

The intention of this document is to speak about topics generally; however, these are the specific versions covered here:

Software	Version(s)
Pentaho	6.x, 7.x, 8.x
Mondrian	3.x

The Components Reference in Pentaho Documentation has a complete list of supported software and hardware.

Core Recipes

This section contains information that is applicable for most analysis scenarios. Topics discussed in this section are as follows:

Learning MDX

MDX is the query language for querying and manipulating multidimensional data stored in OLAP cubes. Analyzer generates MDX statements based on report definitions and then executes them against Mondrian.

Learning MDX begins with browsing through the Mondrian documentation, and then practicing with a few simple MDX queries.

First, try out this tutorial based on `SteelWheels`:

1. Create a new **Analysis Report** using the `SteelWheels` data source.
2. Click the settings wheel, then Administration, and open the **MDX** editor:

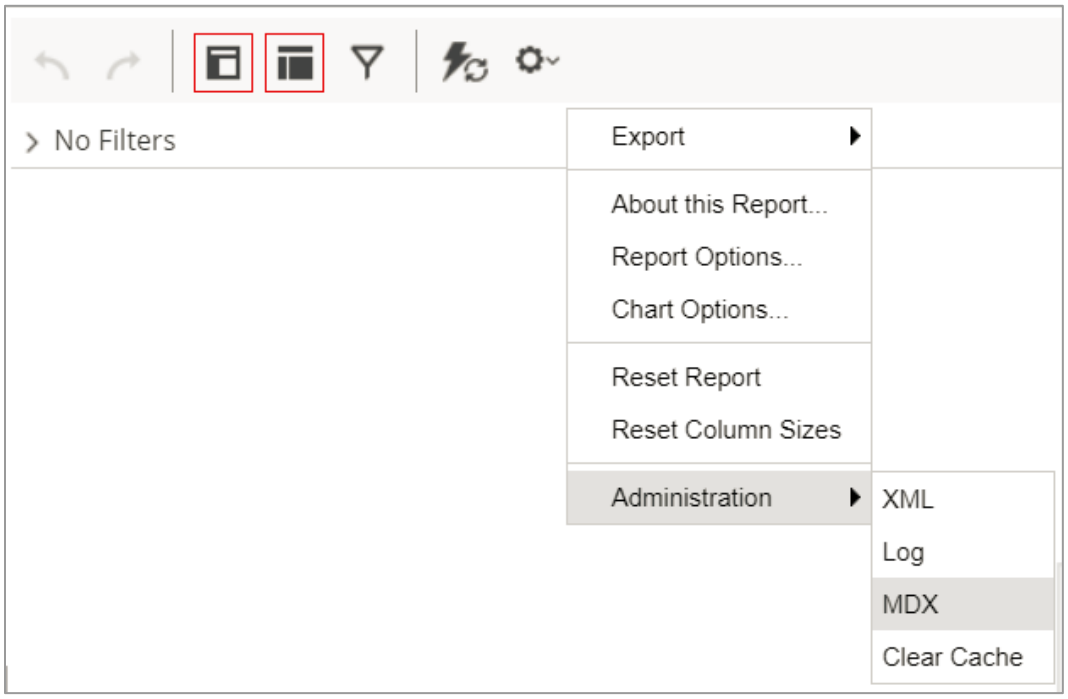


Figure 1: Opening the MDX Editor

3. Enter this MDX statement and select **Execute MDX**:

```
SELECT
        {[Measures].[Sales]} ON COLUMNS,
        {[Markets].[Territory].MEMBERS} ON ROWS
        FROM [SteelWheelsSales]
```

	[Measures].[Sales]
[Markets].[#null]	
[Markets].[APAC]	1,281,706
[Markets].[EMEA]	5,008,224
[Markets].[Japan]	503,958
[Markets].[NA]	3,852,061

Figure 2: Creating a Cube

This simple query places the measure `Sales` on the columns axis, and all members of the `Markets` dimension on the row axis.

4. Cross check your `steelwheels.mondrian.xml` file to make sure you are comfortable with the dimensions and measures defined in the `SteelWheelsSales` cube.
5. Now, use this MDX statement to show `NA` (North America) sales and drill down into the next level of sales (`Country`).

```
SELECT
        {[Measures].[Sales]} ON COLUMNS,
        UNION({[Markets].[NA]},[Markets].[NA].Children) ON ROWS
        FROM [SteelWheelsSales]
```

	[Measures].[Sales]
[Markets].[NA]	3,852,061
[Markets].[NA].[Canada]	224,079
[Markets].[NA].[USA]	3,627,983

Figure 3: Specifying Markets

This query uses the `UNION` MDX function to combine two sets. The first set contains a single `Markets` dimension member `[Markets].[NA]`. `NA` is just a member that comes from the Territory level. The second set calls the `Children` MDX function on the `NA` member, which returns all children of `NA`.

It is simple to get `NA` and child `Canada/USA` sales using a basic MDX expression. If you tried to do this with SQL, it would have been much more complicated and involved several `group-bys`.

6. Finally, calculate each country's percentage (%) contribution to the parent:

```
WITH
      MEMBER [Measures].[% of Total] AS
      '[Measures].[Sales]/([Measures].[Sales],[Markets].CurrentMember.Paren
t)', FORMAT_STRING = '###0.00%'
      SELECT
      {[Measures].[Sales], [Measures].[% of Total]} ON COLUMNS,
      UNION({[Markets].[NA]},[Markets].[NA].Children) ON ROWS
      FROM [SteelWheelsSales]
```

	[Measures].[Sales]	[Measures].[% of Total]
[Markets].[NA]	3,852,061	36.18%
[Markets].[NA].[Canada]	224,079	5.82%
[Markets].[NA].[USA]	3,627,983	94.18%

Figure 4: Calculating Contribution

In this example, we created a new calculated member in the `Measures` dimension called `% of Total`. When this calculated measure is evaluated, the numerator refers to the `Sales` for the current `Market` dimension member coming from the row axis, and the denominator refers to the `Sales` for the parent member of the current `Market` dimension member on the row axis.

This means that whatever `Market` dimension member is on the row axis, the `% of Total` calculates the corresponding contribution correctly. Try this with other territories, such as EMEA, to verify.

For `[Markets].[NA]`, the `% of Total` equals 36.18% because when the current member on the row axis is NA, then the current member's parent refers to the `All` member. The `All` member is a special member that exists in every hierarchy. It is the topmost level, and normally you don't have to include it explicitly when you come up with member unique names. For example, these two are equivalent:

- `[Markets].[All Markets].[NA]`
- `[Markets].[NA]`

***Test your MDX knowledge**: If you wanted the `% of Total` for the `[Markets].[NA]` member to total 100%, but not to use the `All` member in the denominator, how would you modify the `% of Total` calculated measure? The answer appears near the end of the cookbook. Your expected output is:*

	[Measures].[Sales]	[Measures].[% of Total]
[Markets].[NA]	3,852,061	100.00%
[Markets].[NA].[Canada]	224,079	5.82%
[Markets].[NA].[USA]	3,627,983	94.18%

Figure 5: % of Total is 100%

Getting Started with Designing Calculated Measures

You should always start designing and testing your MDX expressions in Analyzer by creating a user defined calculated measure. This allows you to:

- Get used to the MDX syntax.
- Try out different MDX functions.
- Rapidly see MDX parser errors.
- Validate the calculation results.

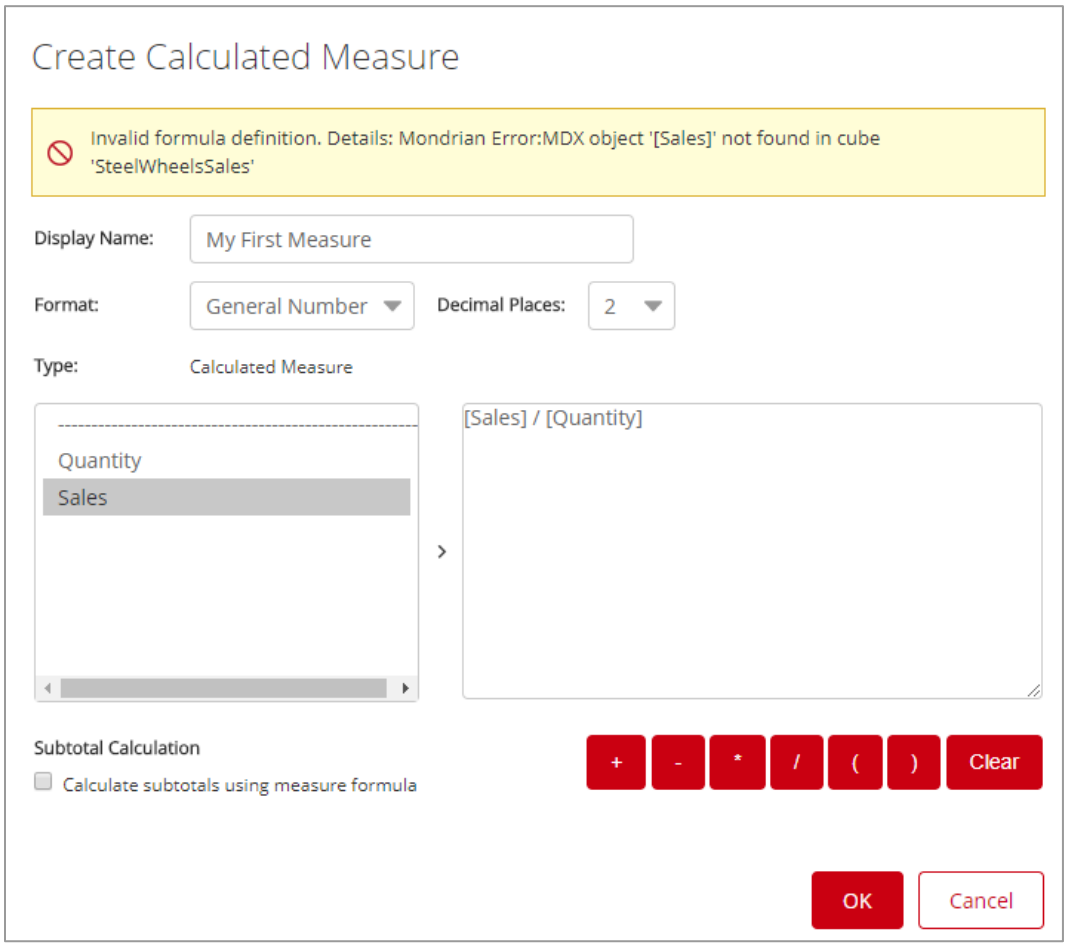


Figure 6: Checking Expressions for Errors

Since Analyzer is based on Mondrian, you should familiarize yourself with what is available in Mondrian.

When you try to use a new MDX function, search online for it since the Microsoft Software Developer Network (MSDN) provides good descriptions of and examples for each function.

When you design MDX expressions, you will need to know dimension, hierarchy, level, and unique member names. You can get some of this from the Mondrian schema file. Alternatively, they are also exposed in Analyzer.

Here are the dimension, hierarchy, and level name for `Territory`:

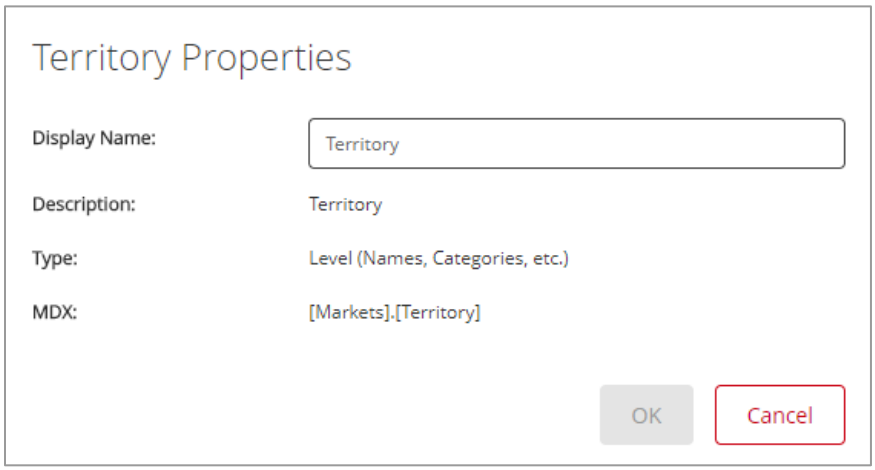


Figure 7: Dimension, Hierarchy, and Level Name

The following figure shows how you can get the `1900s Vintage Bi-Plane` member unique name by looking at the tooltip in the `Product` filter dialogue:

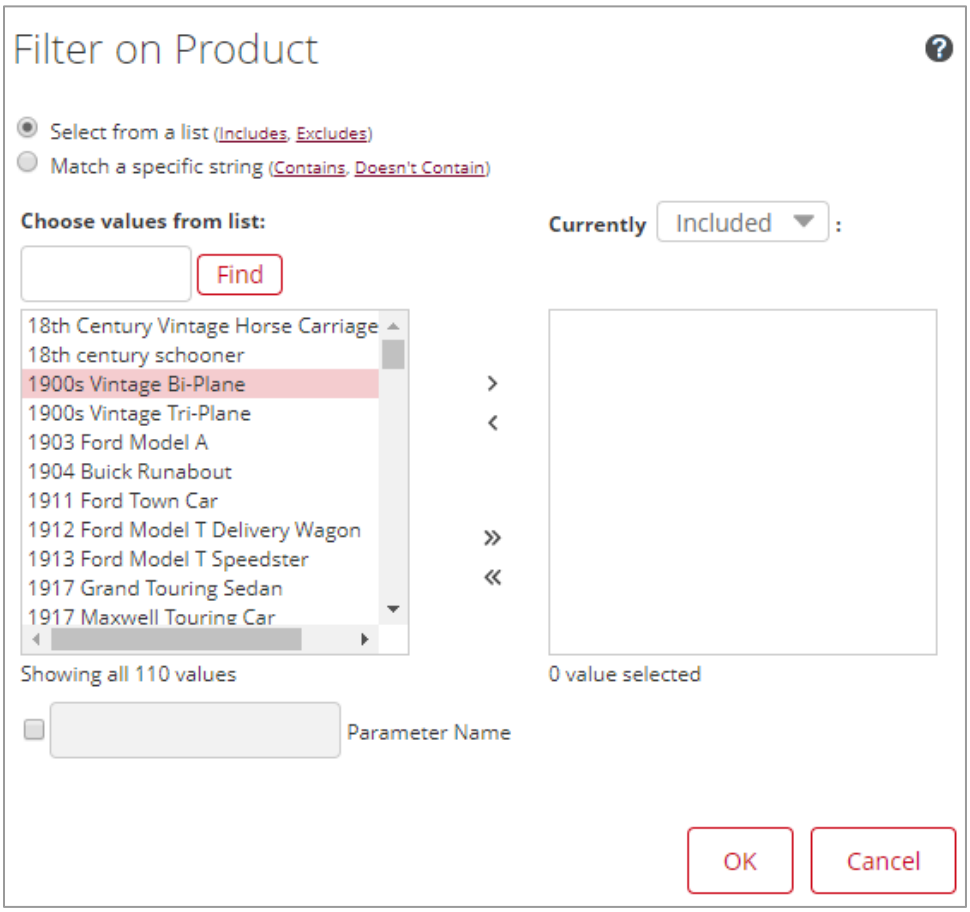


Figure 8: Member Unique Name

You can also design and test MDX expressions directly in Analyzer's **MDX editor**. You must be an Administrator to access this functionality.

Usually, the most effective way to test and debug with the MDX editor is first to build the report, then grab the MDX from the query log, and finally start tweaking the MDX in the editor.

Getting All SQL Statements for a Report

A single Analyzer report may generate one or more MDX statements, and each MDX statement will usually result in multiple SQL statements. Whether SQL statements are executed will depend on what has already been cached in Mondrian. Therefore, it is useful to be able to get all SQL statements that will be generated for a single report, by clearing the cache.

If you are logged in as an Administrator, you will have access to the following admin functionality:

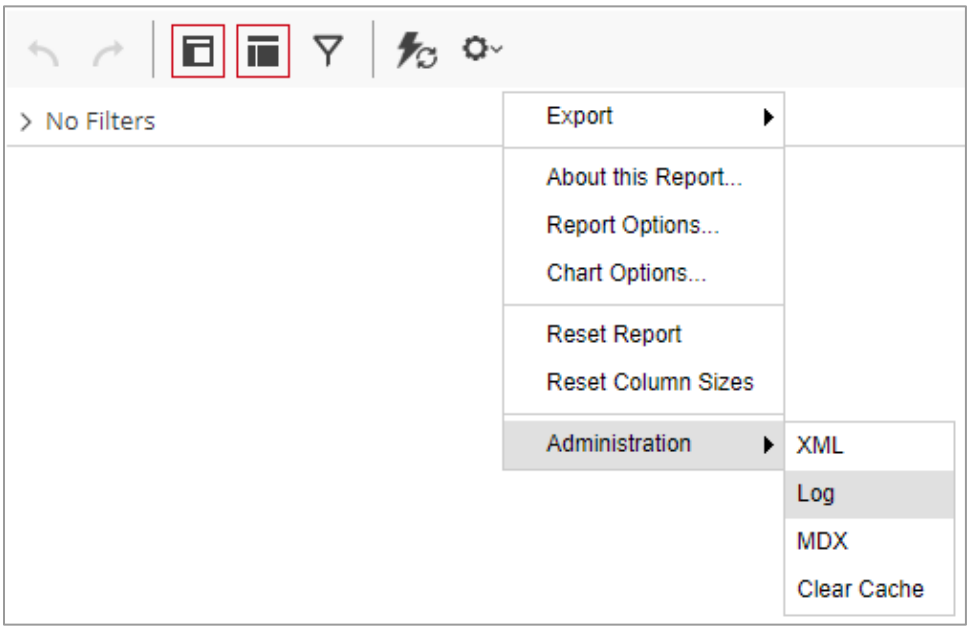


Figure 9: Admin Log

To get all SQL statements for a report:

1. Build the report.
2. Select **Clear Cache**.
3. Select **XML** and then **OK**.
4. Select **Log**.

A new browser window will open with all MDX and SQL statements executed for the report. SQL statements will show up in pairs. The first statement (`exec`) refers to when the first row is returned. The second statement (`exec+fetch`) is when all rows have been read from the query. The last statement breaks down the report total execution time.

Sharing a User Defined Calculated Measure Across Multiple Reports

To share a user defined calculated measure across multiple reports, you will need to **define the measure in the Mondrian schema**. Define the measure within a cube, and it will show up as a calculated measure in the `Measures` dimensions.

Here is an example of a user defined calculated measure, and how it would appear in the Mondrian schema:

```
<CalculatedMember name="Average Sales Price" dimension="Measures">
  <Formula>[Measures].[Sales]/[Measures].[Quantity]</Formula>
  <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00" />
  <CalculatedMemberProperty name="SOLVE_ORDER"
value="200"></CalculatedMemberProperty>
</CalculatedMember>
</Cube>
```

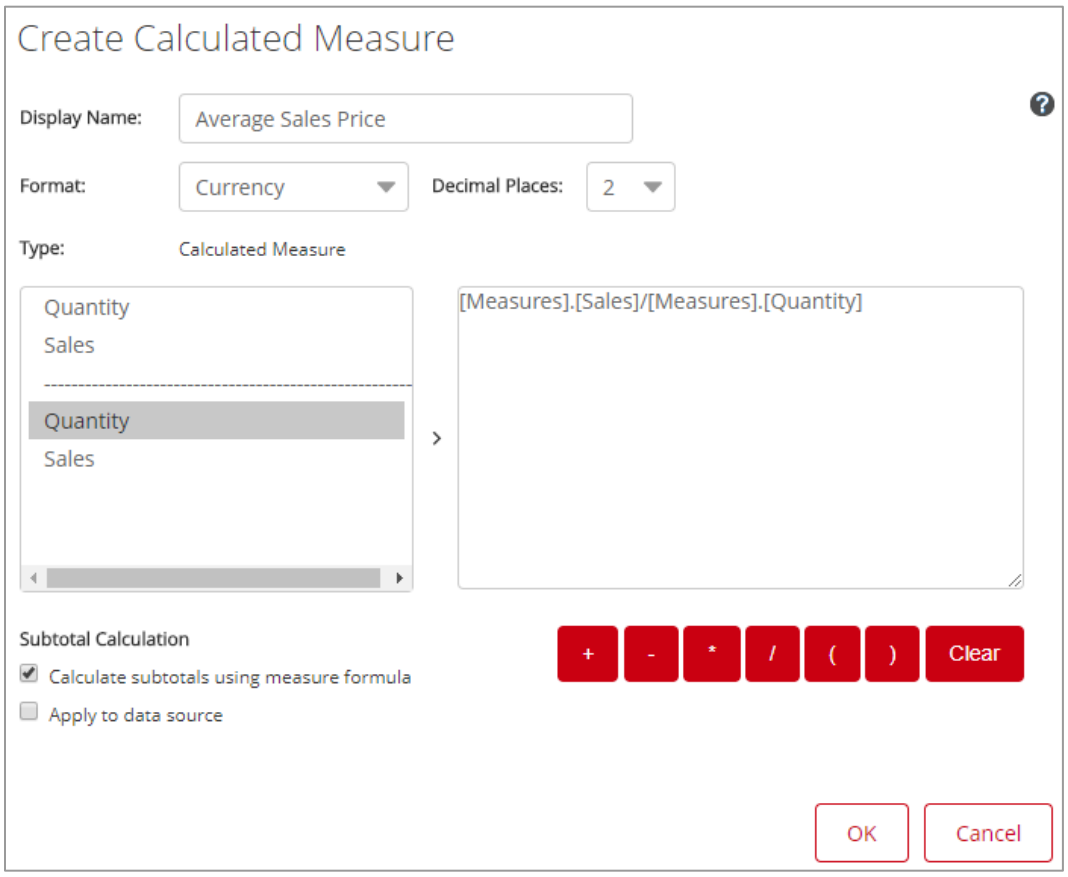


Figure 10: Calculated Measure

Here are a few things to keep in mind when converting the MDX expression used in the report to the one that will be used in the schema:

- References to measures such as `[Sales]` or `[Quantity]` need to be prefixed with the dimension, so update them to `[Measures].[Sales]` or `[Measures].[Quantity]`.
- Make sure your MDX expression does not refer to user defined numbers that were defined on the report, as they will obviously not exist in the schema.
- Set the `SOLVE_ORDER` using a `CalculatedMemberProperty`.
    - If you are running Analyzer 5.0 or later, and you checked the **Calculate subtotals using formula** box, then set `SOLVE_ORDER` to `200`. If you did not check the box, do not set this property.
    - Set the `FORMAT_STRING` using a `CalculatedMemberProperty`. For static format strings, you will set the `value` attribute in the `CalculatedMemberProperty`. For dynamic format strings based on MDX expressions, you will set the `expression` attribute on the `CalculatedMemberProperty`. Format strings are mapped as follows:

Table 1: Format String Mapping

Format String Attribute	Formatting
General Number	`#,##0.0`
Currency	`$#,##0.00`
Percentage	`###0.00%`

Here is an example of a dynamic format string:

```
<CalculatedMember name="Style Unit Sales" dimension="Measures">
  <Formula>[Measures].[Unit Sales]</Formula>
  <CalculatedMemberProperty name="FORMAT_STRING" expression="
      IIf([Measures].[Unit Sales] > 100000,
           '|#,###|style=green',
           IIf([Measures].[Unit Sales] > 50000,
               '|#,###|style=yellow',
               '|#,###|style=red'))" />
</CalculatedMember>
```

Basic Recipes

Here, you will find information on out of the box examples supported by Analyzer, where no experience is necessary. Topics covered in this section are as follows:

Showing Rows with No Data

Normally, Analyzer will filter out combinations of dimension members that have no data. No data means that either the measure value is null or that there is no such tuple in the fact table. However, you can show these empty cells by changing the report option **Show rows or columns with** to **Show all even blank measures**.

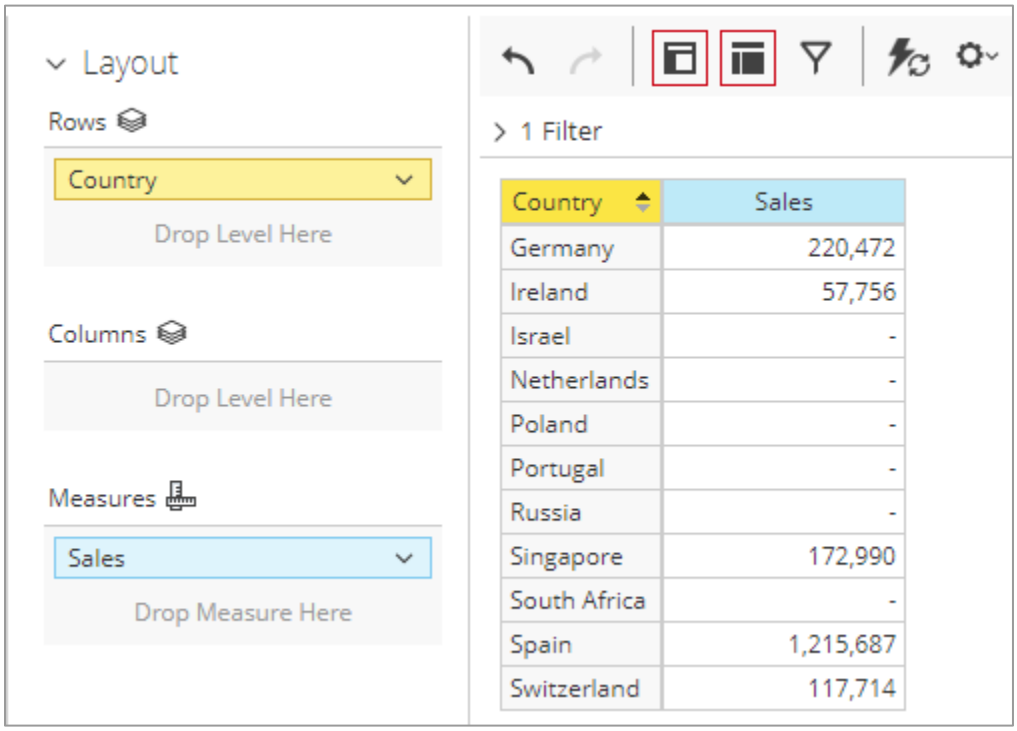


Figure 11: Showing Rows with No Data

*Be careful with performance when using this feature. When you enable this option, all dimension members from each dimension will be cross-joined together. So, if you had three dimensions with 100 members each, your report would contain 100*100*100 = 1,000,000 rows.*

Creating a Subtotal on Distinct Count Measures

Remember to create this at the schema level as described in Sharing a User Defined Calculated Measure Across Multiple Reports.

A distinct count measure is a measure defined in the Mondrian schema with:

```
aggregator = "distinct-count"
```

When showing the subtotal for a distinct count measure, you may want a straight sum of all the details rows, or you may want to compute the distinct count of transactions records in that total.

In this example, based on `Foodmart`, `Grand Total` will double count customers who have bought more than one product, whereas the `Grand Aggregate` will only count each customer once.

Product Family	Customer Count
Drink	1,753
Food	2,735
Non-Consumable	2,206
Grand Total	**6,694**
Grand Aggregate	**2,755**

Figure 12: Customer Count Table

You can show `Grand Total` and `Grand Aggregate` totals by right-clicking **Customer Count** and selecting the **Subtotals (Sums, Averages, etc.)** menu option:

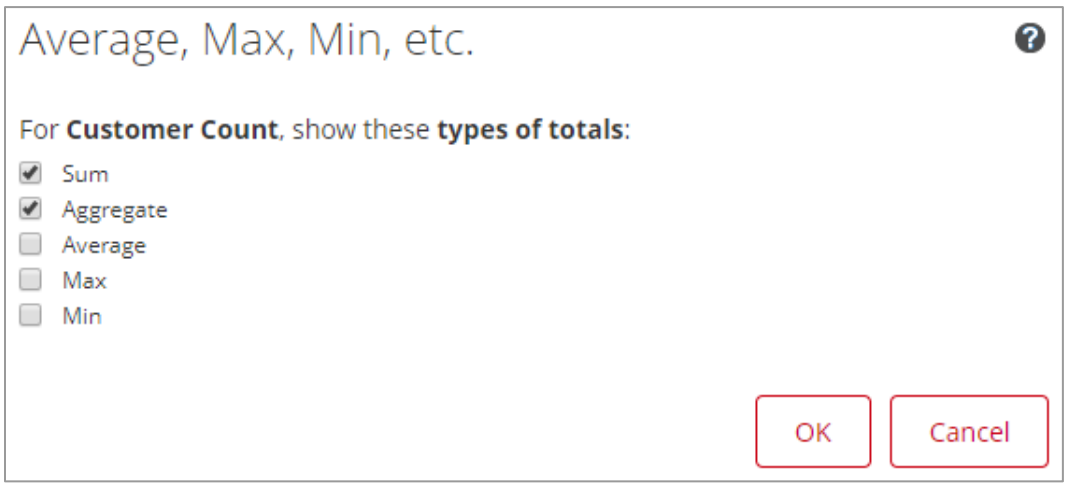


Figure 13: Showing Total Types

Comparing Top 10 Customers Versus All Customers

To compare sales for the top 10 customers versus all customers, you need to compare the two groups side by side. You can do this with a `Top 10` filter. Click on report options at the bottom and choose **Totals with filtered values**.

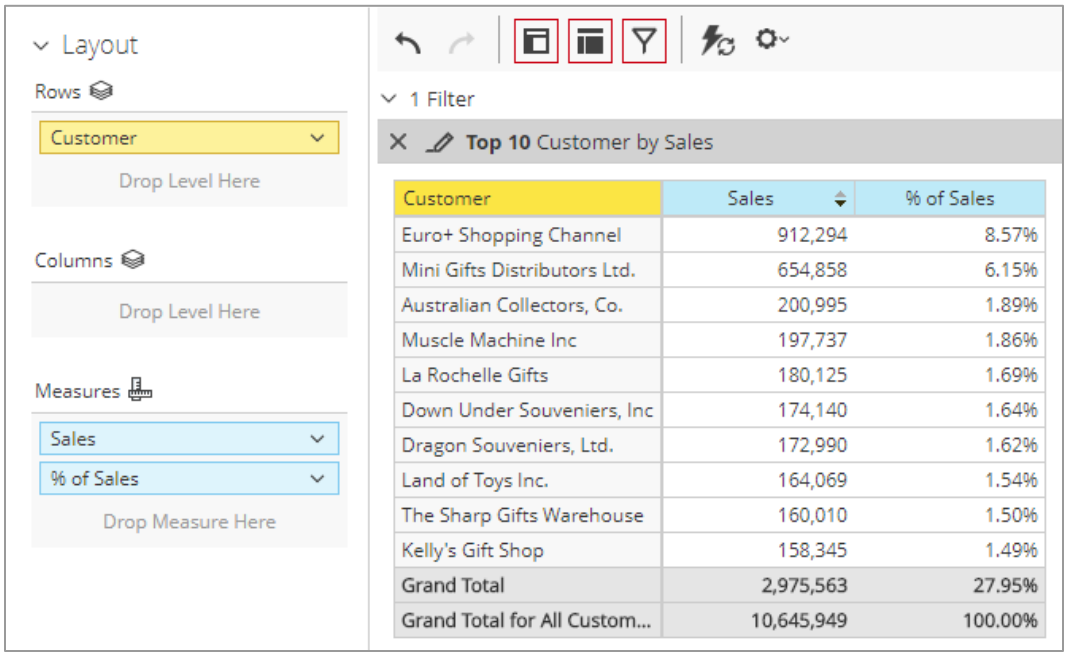


Figure 14: Top 10 Customers Sales

Creating a Pareto Chart

You can use a Pareto chart to highlight the most important of a large set of factors. For example, this chart shows that the top three countries result in 55.93% of total sales:

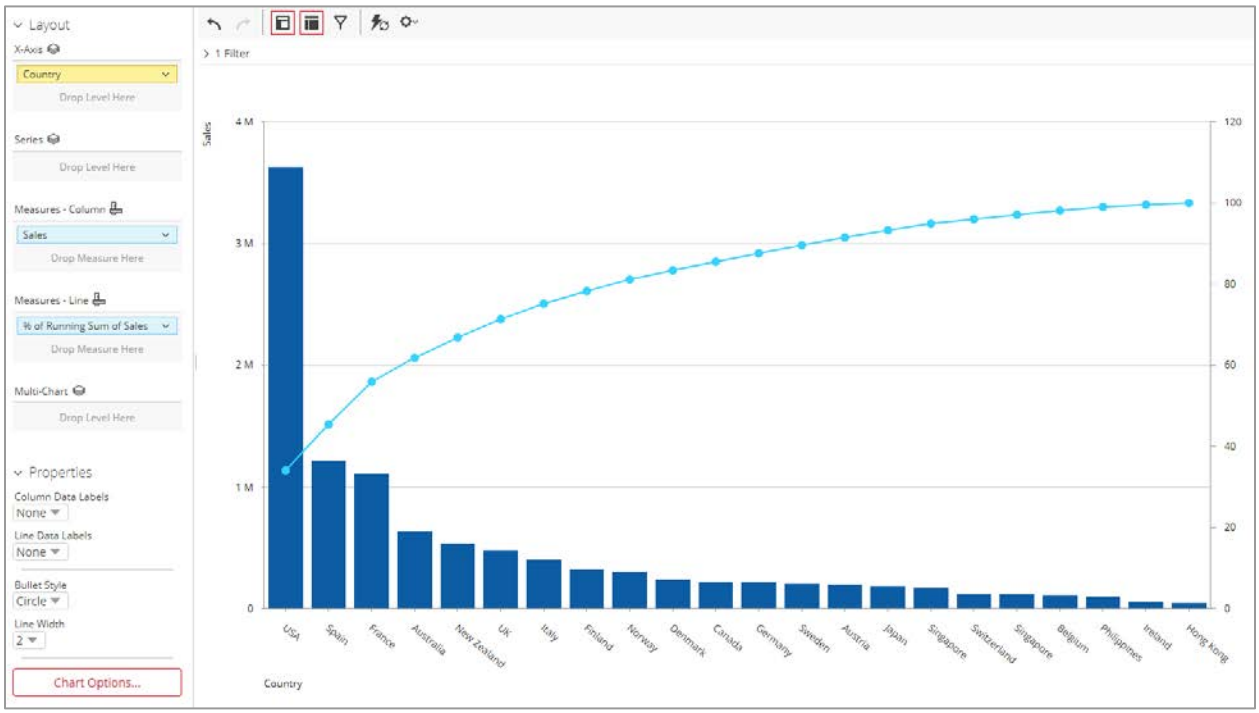


Figure 15: Pareto Chart

Create this Pareto chart by using a Column-Line Combo chart where the Measures – Column contains the `Sales` and the Measures – Line contains a `% Running Sum of Sales` (that is, a `% Cumulative Sales`). To do this, using the example above:

1. In PUC, create a new Analysis Report and choose your data source.
2. Once the report has opened, on the top right, change the view to Chart by clicking here:

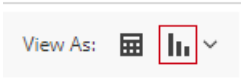


Figure 16: View As Chart

3. Click the drop-down next to the chart view icon, and change the chart type to **Column-Line Combo**.
4. Drag the `Country` market to the **X-Axis** of the chart, and the `Sales` measure to the **Measures - Column** section in **Layout**.
5. Create the `% Running Sum of Sales` with a user defined `% of Running Sum` measure:
    a. Click the drop-down by **Sales** and choose **User Defined Measure** > **% of, Rank, Running Sum**.

b. Choose the measure field **% of Running Sum of Sales** and click **Next**:

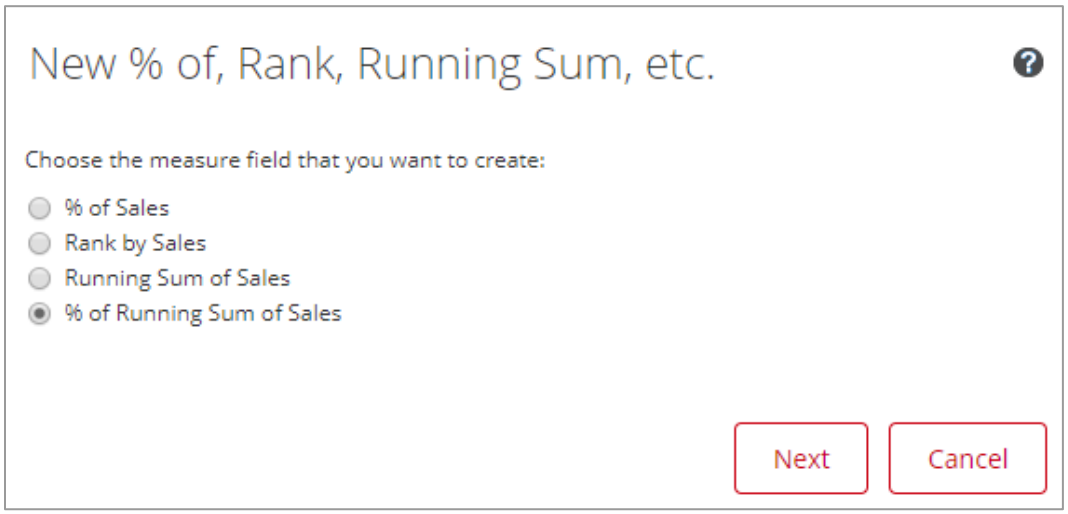


Figure 17: Creating New Measure

6. Configure the measure as follows and click **Done**:

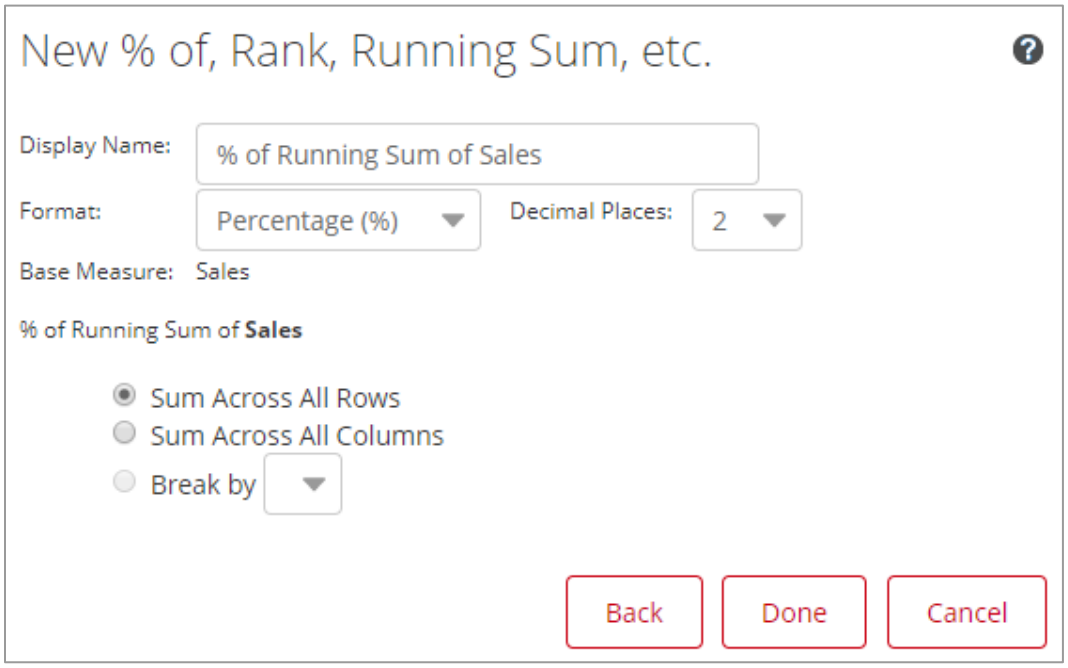


Figure 18: Configuring `% Running Sum of Sales` Measure

7. Finally, order the chart values by clicking the drop-down by **Sales** and choosing **Sort Values High -> Low**:

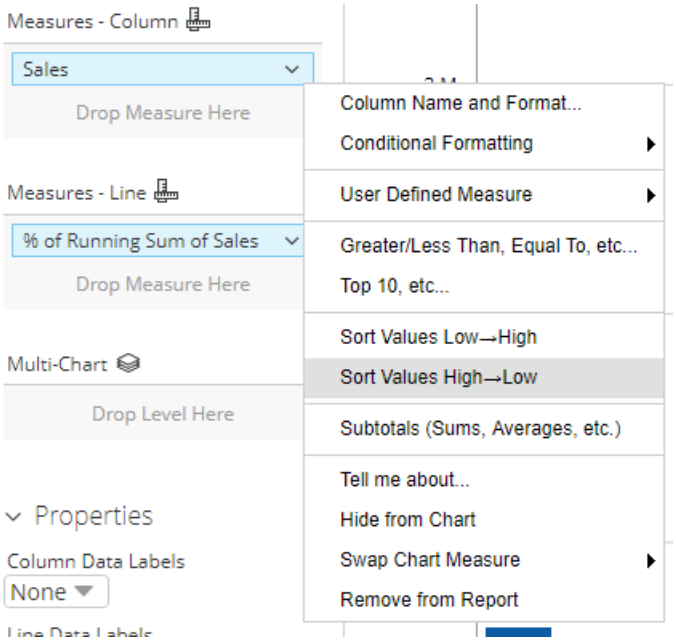


Figure 19: Sort Values

Creating a Moving Average Calculation

A moving average calculation calculates the current period by taking the average of *N* number of previous periods. This is useful for smoothing out a time series, as shown:

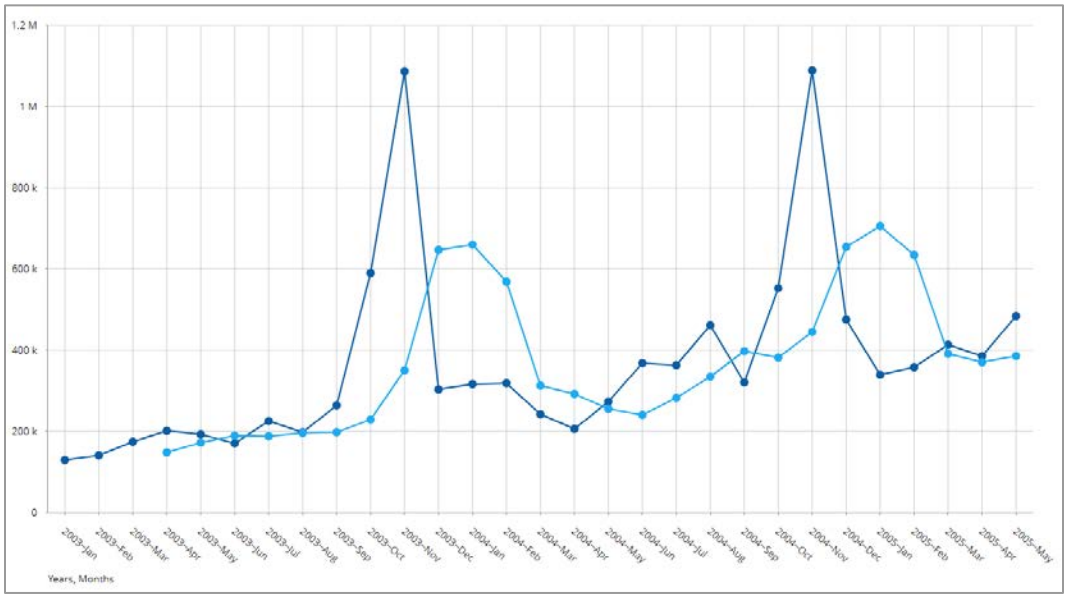


Figure 20: Moving Average Calculation

Create the moving average calculation by clicking **Sales** and choosing **User Defined Measure** and **Trend Measure**.

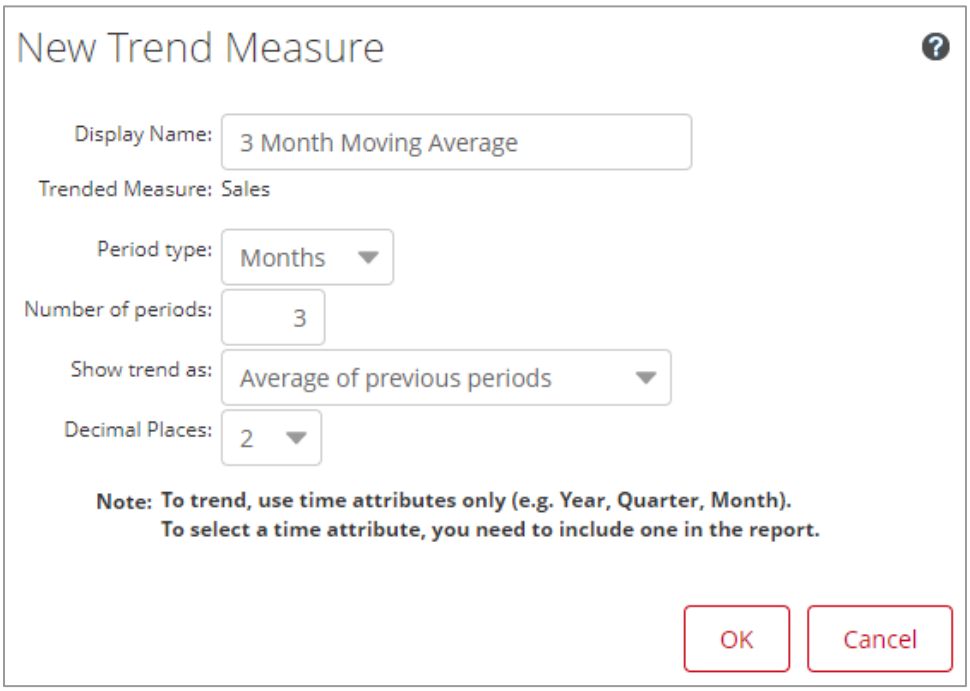


Figure 21: Creating Trend Measure

Creating a Relative Date Filter (Current Year, Next N Years, N Years Ago)

When you are filtering on dates, you may want to use relative date filters instead of absolute date filters. Analyzer provides many filtering options.

These "commonly used time periods" are available only if you have set the `levelType` of time in the Mondrian schema, and `AnalyzerDateFormat` annotation.

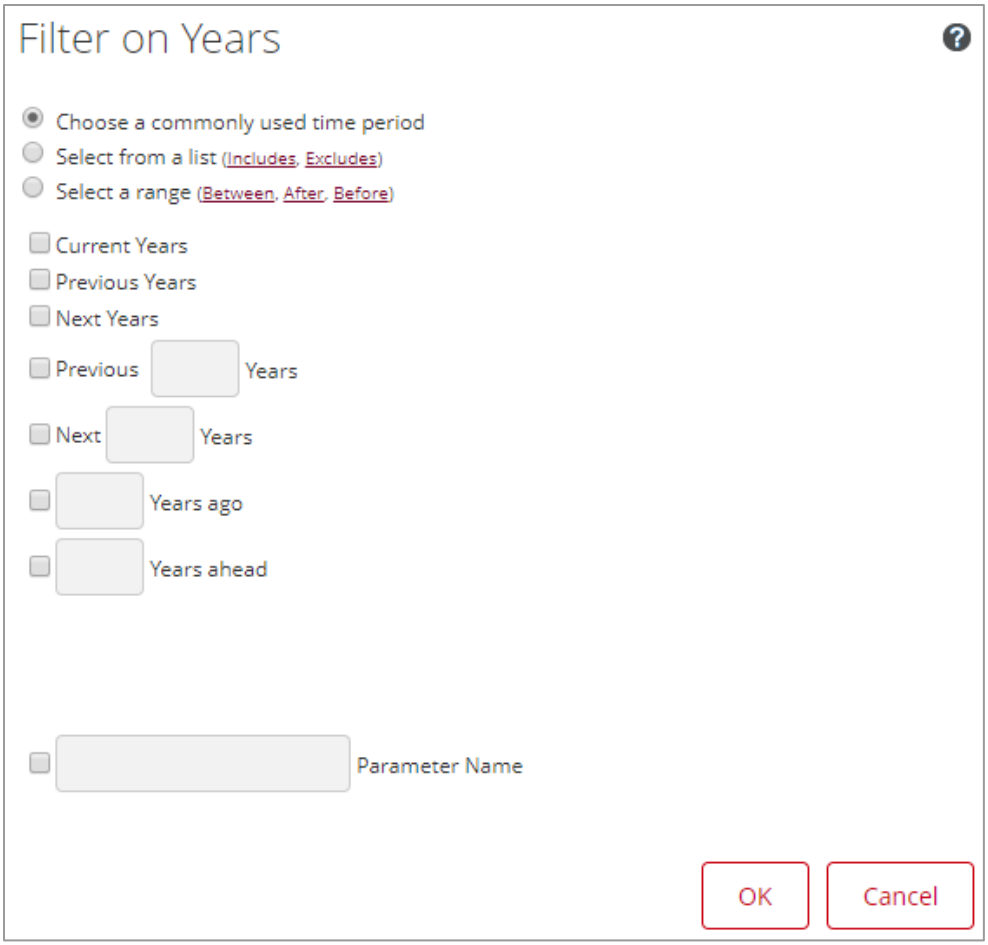


Figure 22: Filter on Years

Further information on setting up relative date filters is available at Enable Relative Date Filters in Mondrian in the Pentaho documentation.

Aggregate Total Type

The aggregate total type is a special total type which aggregates the report details rows using the underlying relational measure aggregator. In the Mondrian schema file, relational measures can have the following aggregators: `sum`, `count`, `min`, `max`, `avg`, `distinct count` and `distinct-count`.

Although `distinct count` (without the hyphen) is still included for backwards compatibility, you should use `distinct-count` for anything new.

The aggregate total type totals values for count, distinct count, and distinct-count on the back end. If you define your measure using any of those aggregators, then the total type must be `aggregate`:

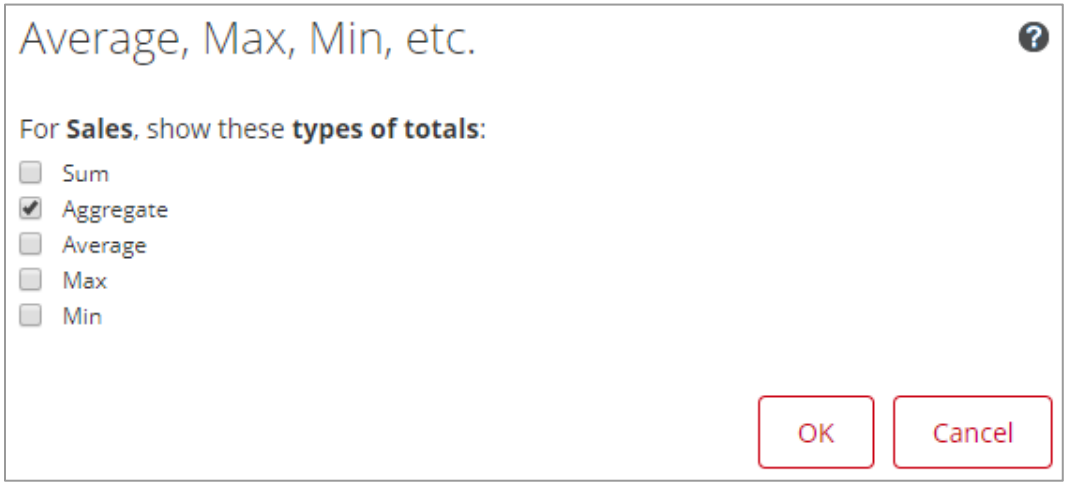


Figure 23: Average, Max, Min, etc.

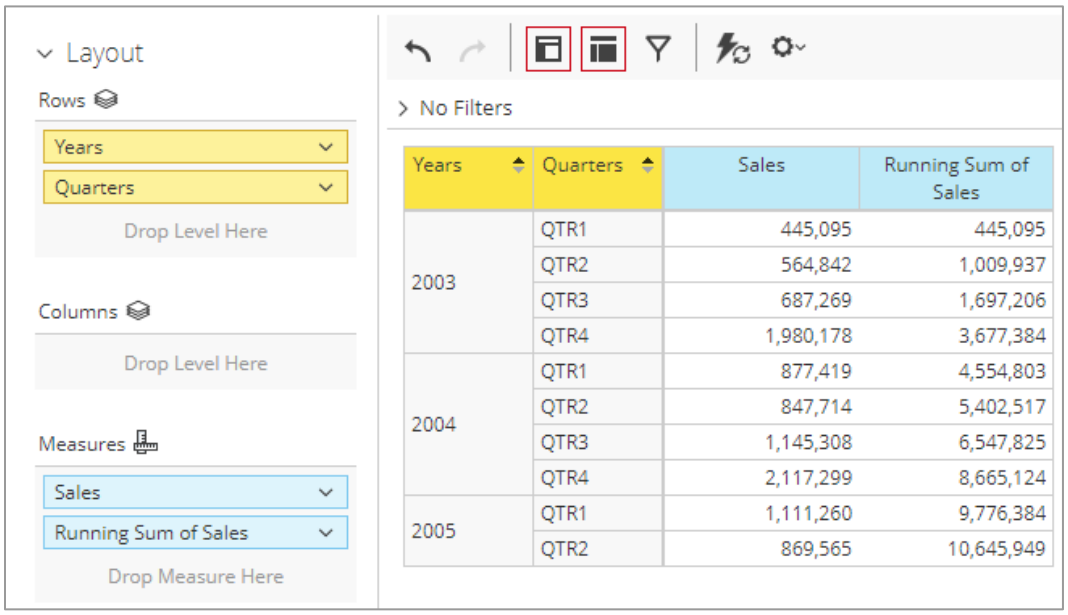
The aggregate total type is particularly useful for `distinct-count` subtotals, because the total needs to remove duplicates from report details rows.

Keep these things in mind when you are using calculated measures with aggregate totals:

- The solve order of the calculated measure must be greater than the aggregate total calculated member. The aggregate total calculated member always has a `-100` solve order.
- When a calculated measure contains a ratio, the total will calculate a ratio of sums (assuming the numerator and denominator are both based on relational measure with an aggregator sum).
- A calculated measure like `[Sales]/100` will divide the total sales by 100 instead of summing up all details sales divided by 100.
- Be careful if your calculated measure MDX expression refers to dimension members coming from the same dimension as the total. The current evaluation context will most likely then be the `All` member instead of the members in the total.

Creating a Running Sum or Cumulative Calculation

A cumulative calculation is like a running sum, useful for continuously adding up a measure over time. This could be used for a Year-to-Date (YTD) calculation:



Years	Quarters	Sales	Running Sum of Sales
2003	QTR1	445,095	445,095
	QTR2	564,842	1,009,937
	QTR3	687,269	1,697,206
	QTR4	1,980,178	3,677,384
2004	QTR1	877,419	4,554,803
	QTR2	847,714	5,402,517
	QTR3	1,145,308	6,547,825
	QTR4	2,117,299	8,665,124
2005	QTR1	1,111,260	9,776,384
	QTR2	869,565	10,645,949

Figure 24: Cumulative Calculation

The Running Sum of Sales was created by clicking **Sales** and selecting **User Defined Measure**, then **% of**, **Rank**, **Running Sum**.

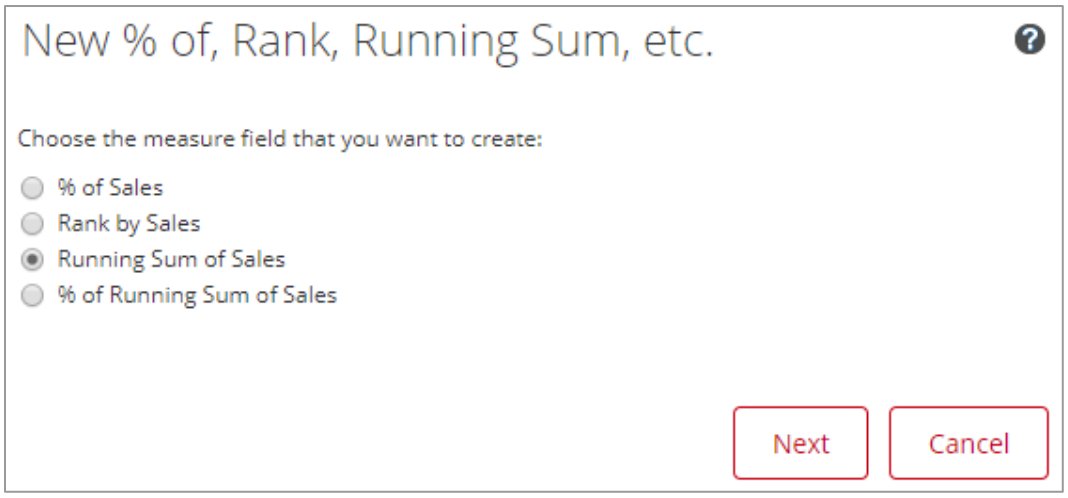


Figure 25: New % of, Rank, Running Sum

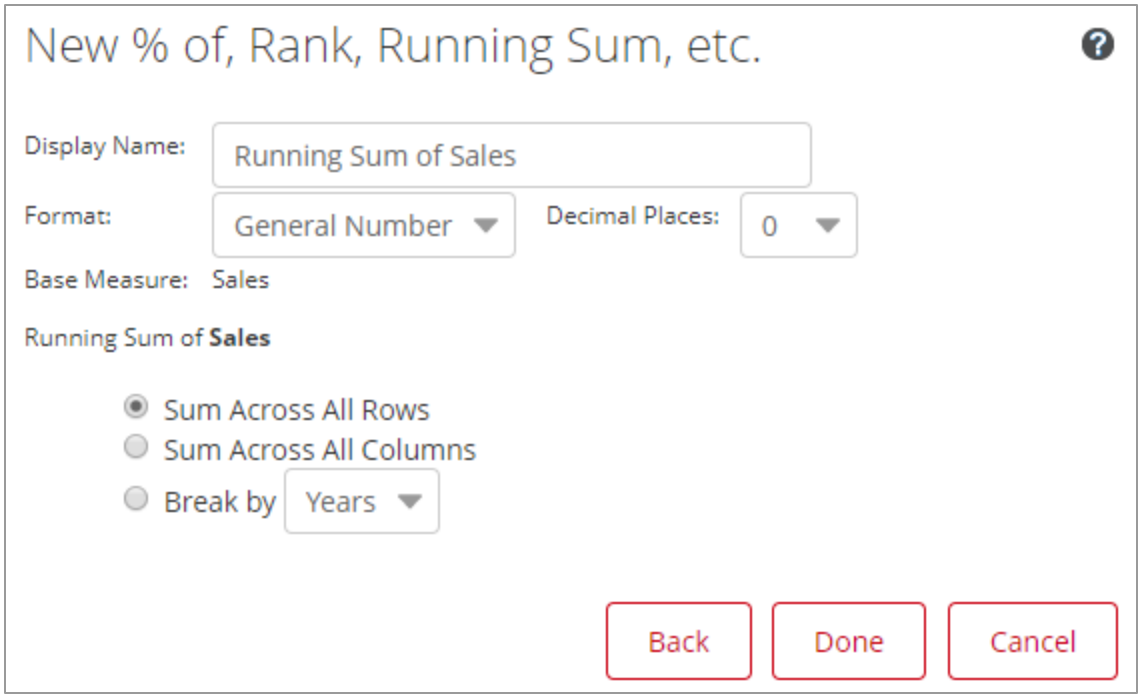


Figure 26: Running Sum of Sales

If you want to reset the running sum for each year, choose the **Break by Years** radio button.

Percent Change Year Ago Calculation

A percent change year ago calculation will tell you the percent change between this period and the same period a year ago (YAGO).

This calculation will work regardless of whether you use quarters, months, weeks, or days, as long as the position of the period is the same in this year and the previous year.

Here is an example:

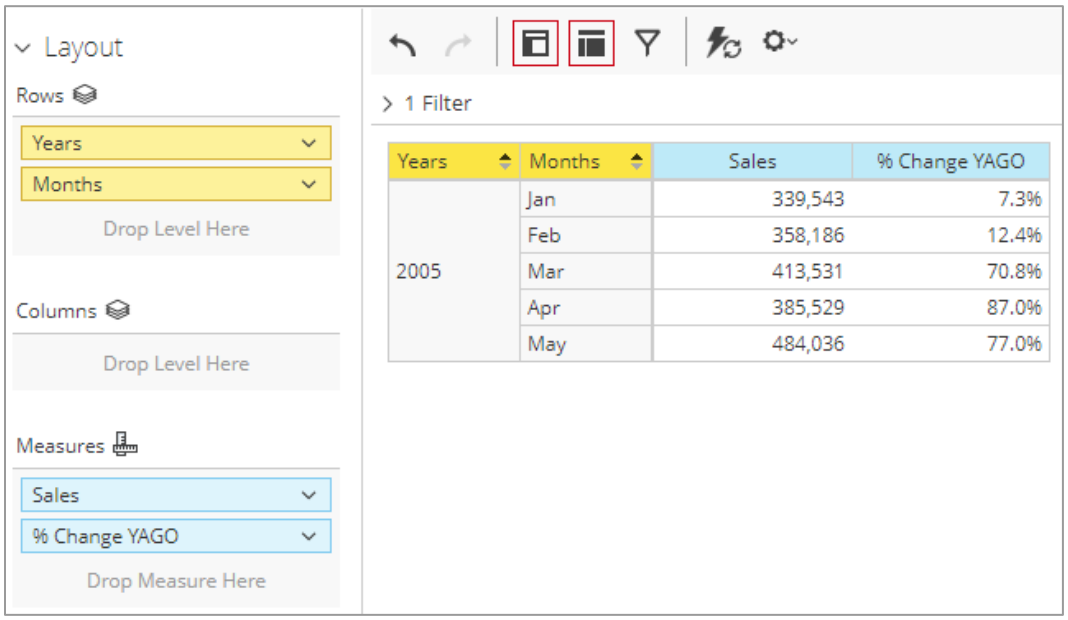


Figure 27: % Change YAGO Calculation

For example, February is calculated as $\left(\frac{\texttt{Sales in February 2005}}{\texttt{Sales in February 2004}}\right)$ -1.

Create this calculation by clicking **Sales**, and choosing **User Defined Measure** and **Trend Measure**.

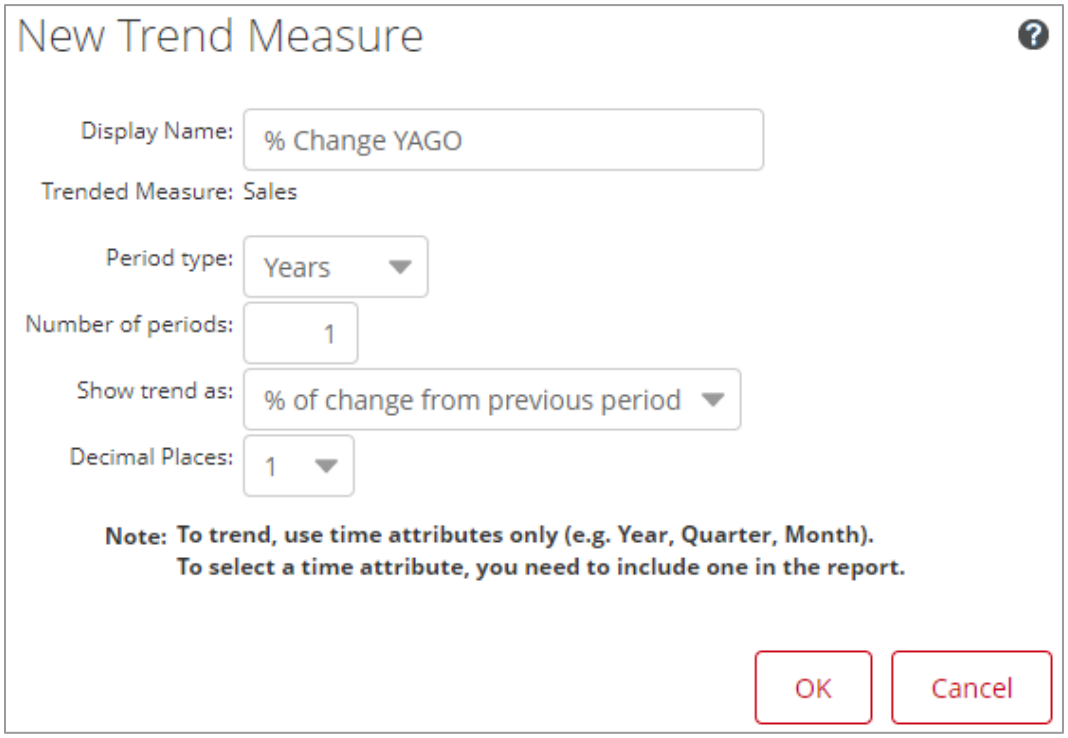


Figure 28: Creating % Change YAGO Trend Measure

Advanced Recipes

In this section, you will find information on use cases that require an understanding of MDX expressions and how they are evaluated. This section covers topics such as:

Pinning a Measure to Specific Dimension Measures

A measure that is pinned to specific dimension measures will always be evaluated by those pinned members, regardless of what is on the rows or columns. For example, this report below has APAC `Sales` and APAC + Japan Sales pinned to their respective countries:

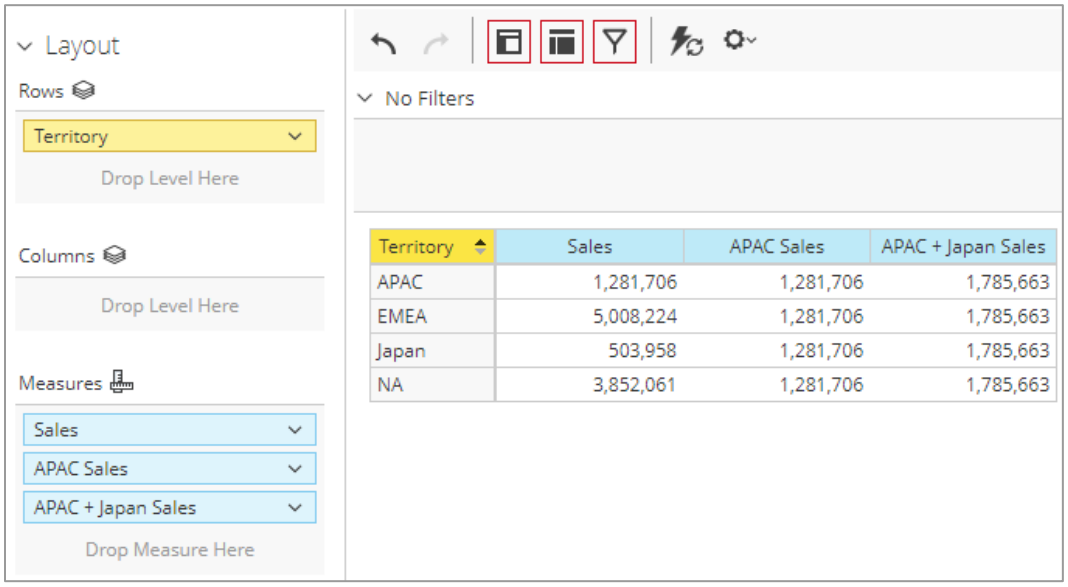


Figure 29: APAC `Sales` and APAC + Japan `Sales`

APAC `Sales` is pinned to APAC:

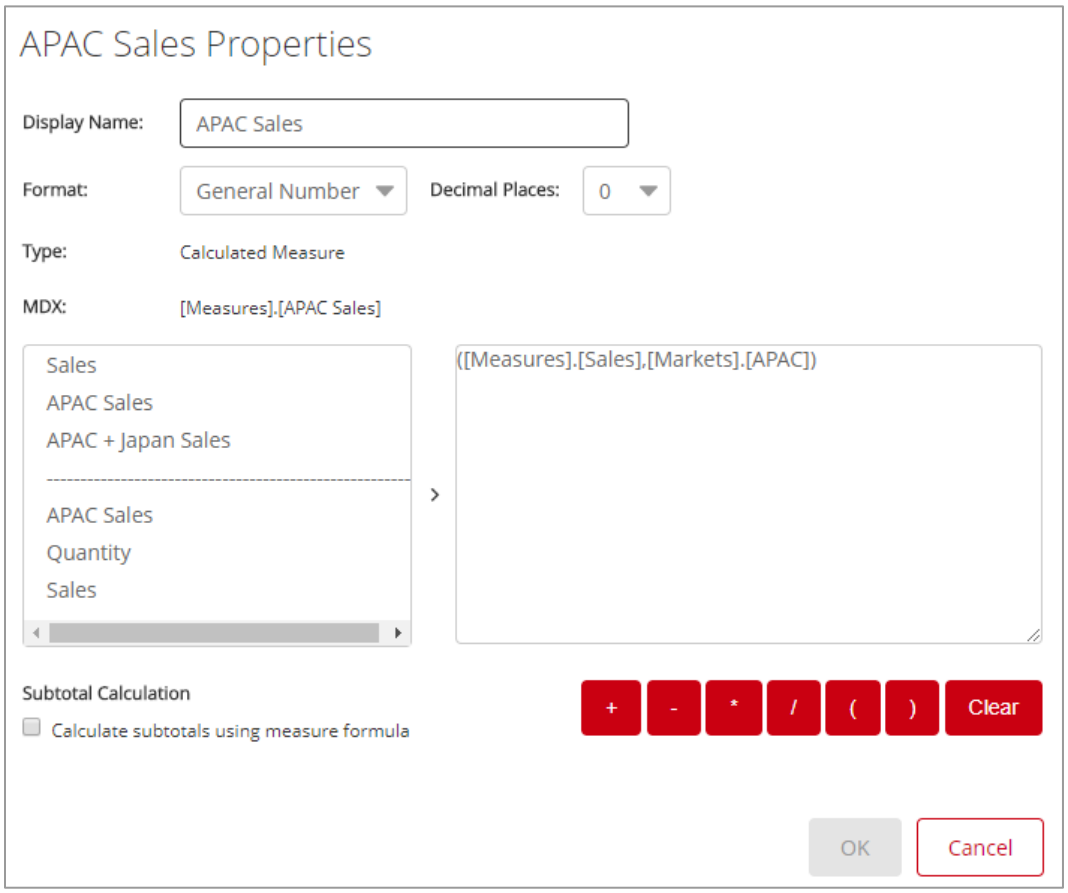


Figure 30: Pinning APAC `Sales` to APAC

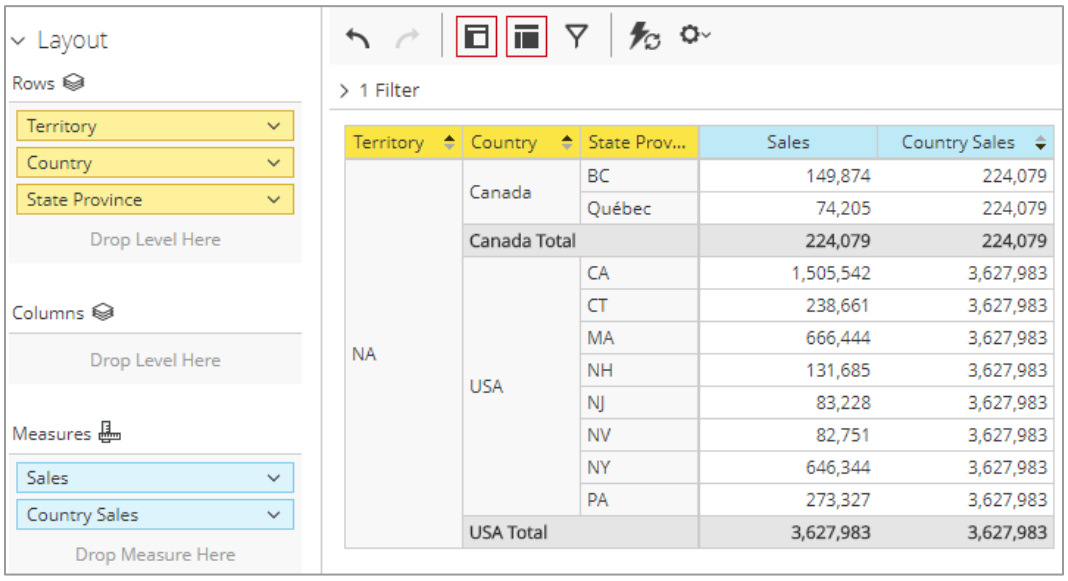
For APAC `+ Japan Sales`, use the `Sum` function, since there is more than one territory:

```
Sum({[Markets].[APAC],[Markets].[Japan]}, [Measures].[Sales])
```

Pinning a Measure to a Specific Hierarchy Level

When you pin a measure to a specific hierarchy level, that measure will always roll up to that level, regardless of what levels are on the report. This type of measure is sometimes known as a level based measure.

For example, in `SteelWheels`, the `Markets` dimension has a hierarchy with `Territory` → `Country` → `State` → `City` levels. This example shows a measure called `Country Sales` which is pinned to the `Country` level:



Territory	Country	State Prov...	Sales	Country Sales
NA	Canada	BC	149,874	224,079
		Québec	74,205	224,079
	Canada Total		224,079	224,079
	USA	CA	1,505,542	3,627,983
		CT	238,661	3,627,983
		MA	666,444	3,627,983
		NH	131,685	3,627,983
		NJ	83,228	3,627,983
		NV	82,751	3,627,983
		NY	646,344	3,627,983
		PA	273,327	3,627,983
	USA Total		3,627,983	3,627,983

Figure 31: `Country Sales` Measure

The `Country Sales` measure is defined as follows:

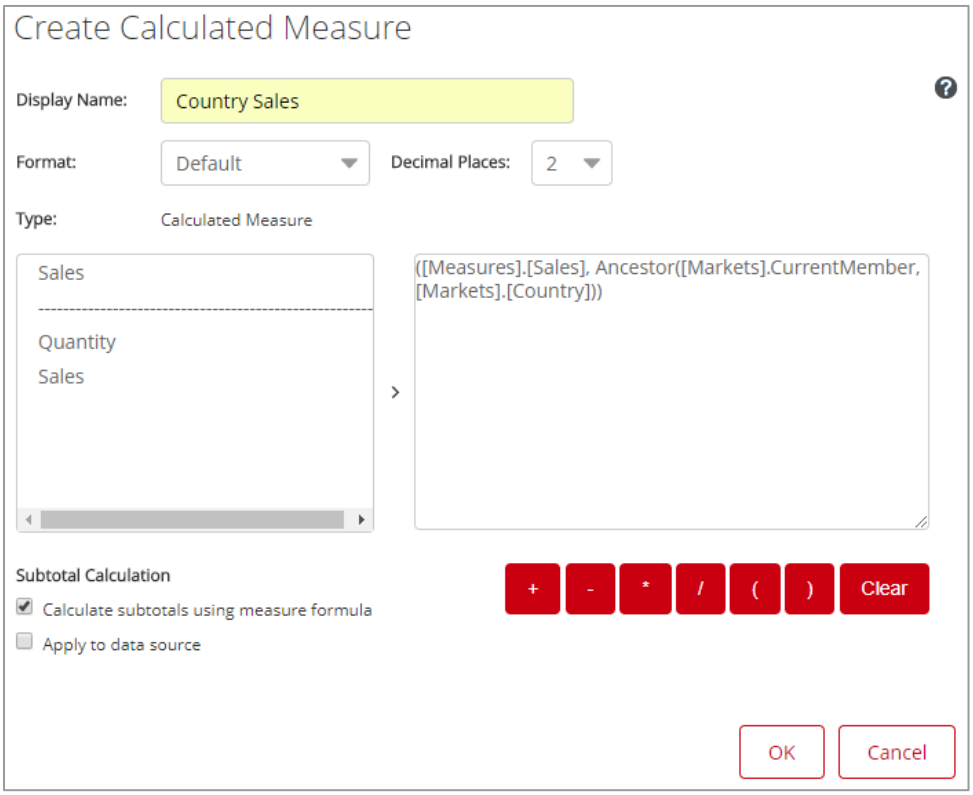


Figure 32: Creating the `Country Sales` Measure

If your report contained only `Territory`, then you would get no data, because there is no ancestor above any `Territory` member that is at the `Country` level.

If, however, you just wanted to return `Sales` for that `Territory`, you could use the expression in the following figure:

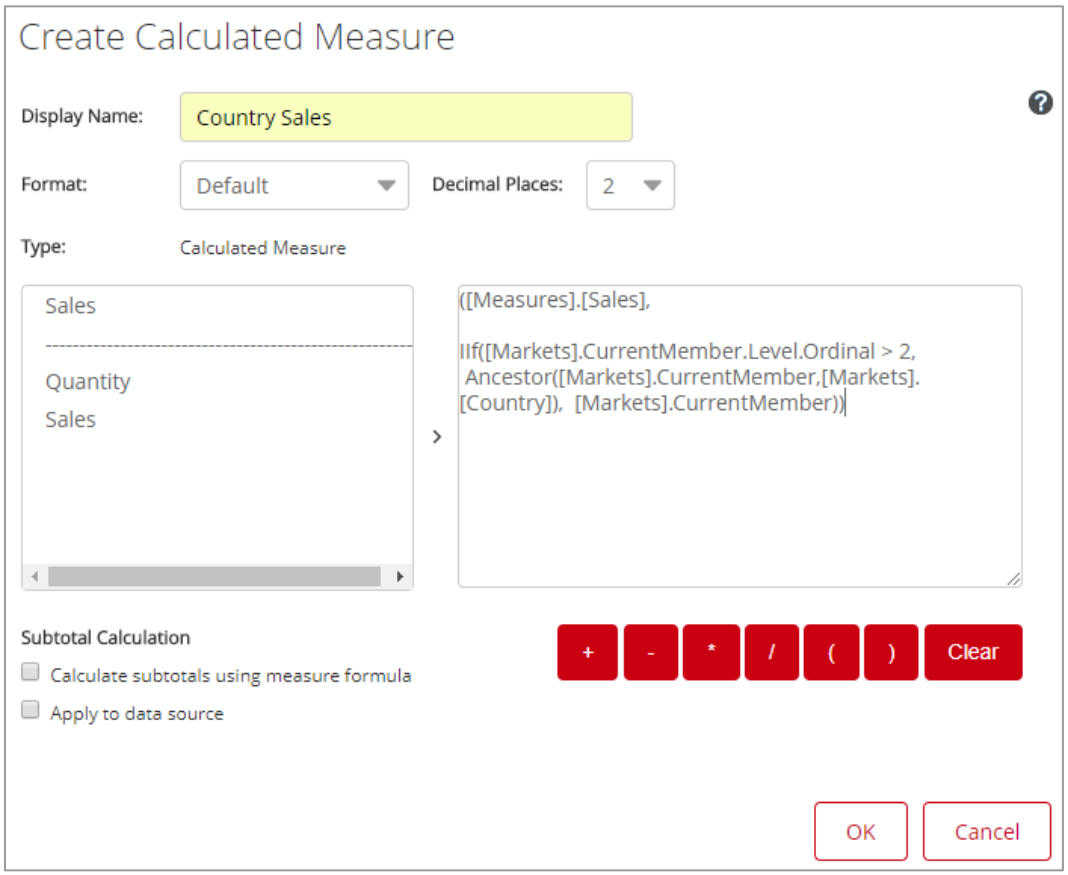


Figure 33: Calculating Sales for a Territory

In this expression, you can check the `Markets` current member's level ordinal to determine what level is on the report, and then conditionally pick the `Country` ancestor or the current member.

Remember that ordinal 0 is the `All` level, ordinal 1 is the `Territory` level, ordinal 2 is the `Country` level, and so forth.

Creating Semi-Additive Measures

A semi-additive measure is a measure which does not uniformly aggregate across all dimensions within a cube. A common example would be a snapshot of account balances over time, such as bank account balances or inventory level balances. It would not make sense to add up all monthly bank account balances within a year. Instead, you would define whether you wanted the last account balance or the average account balance in the year.

There are many different types of semi-additive functionality, including `first child`, `last child`, `count`, `min`, `max`, and `average`.

In this example, use these monthly snapshots of an account balance:

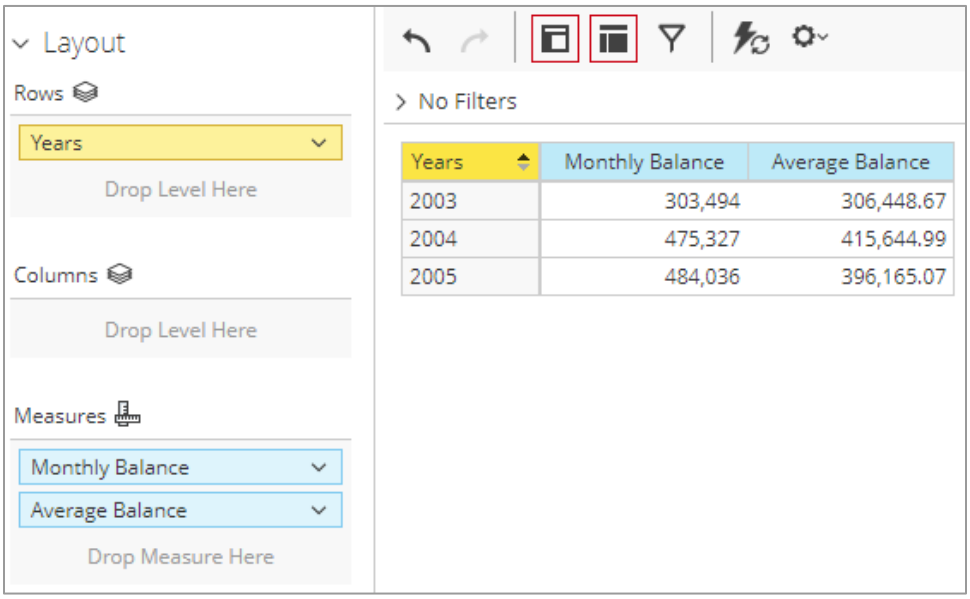


Figure 34: Monthly Account Balances

`Monthly Balance` shows the last month for the year, while `Average Balance` shows the average balance for the year. Create the user defined measure `Monthly Balance` this way:

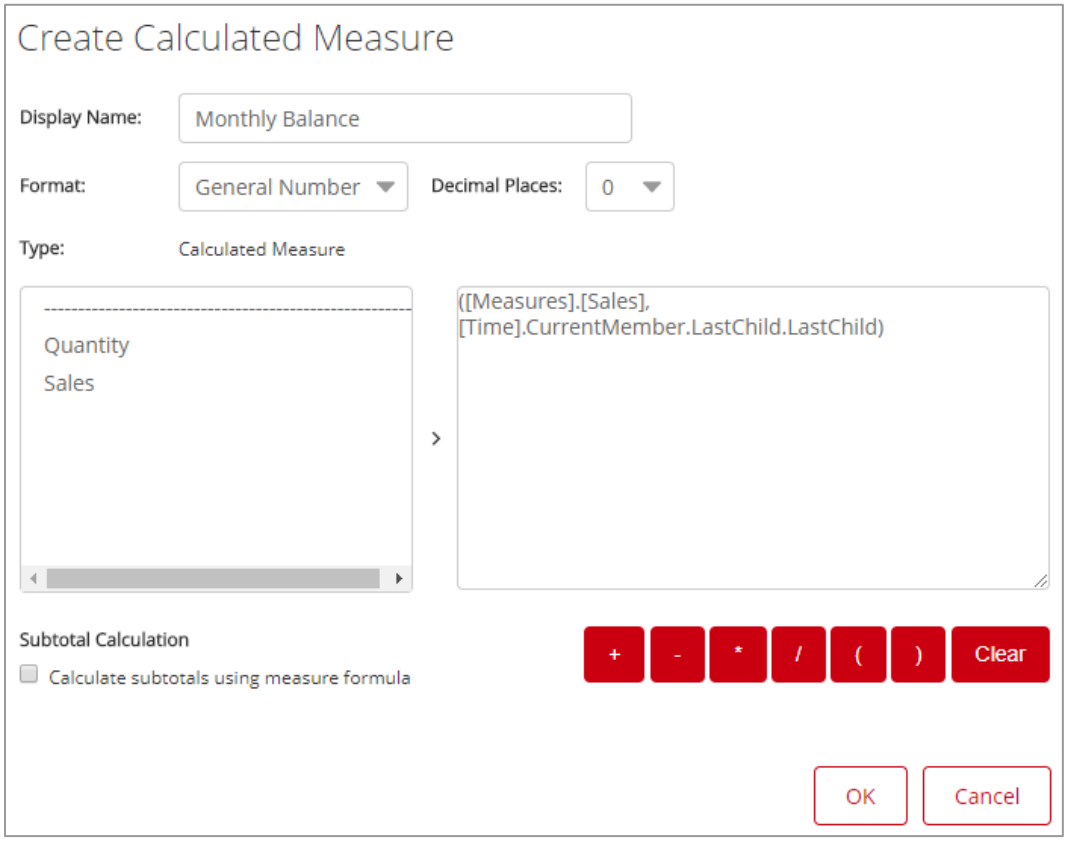


Figure 35: Creating `Monthly Balance` Measure

This MDX expression assumes that the current time member is at the `Year` level, and that we can directly ask for the `last child` twice to go from `Year` → `Quarter` → `Month`.

A more robust way to get the last month balance is with this MDX expression:

```
([Measures].[Sales],Tail(Descendants([Time].CurrentMember,
[Time].[Months]),1).Item(0))
```

This expression will work regardless of whether you have `Years` or `Quarters` on the report, because it will use the `Descendants` function to get all `Month` level descendants for the current `Year` or `Quarter`. It uses the `Tail` function to get the last item in the set.

Create the `Average Balance` as follows:

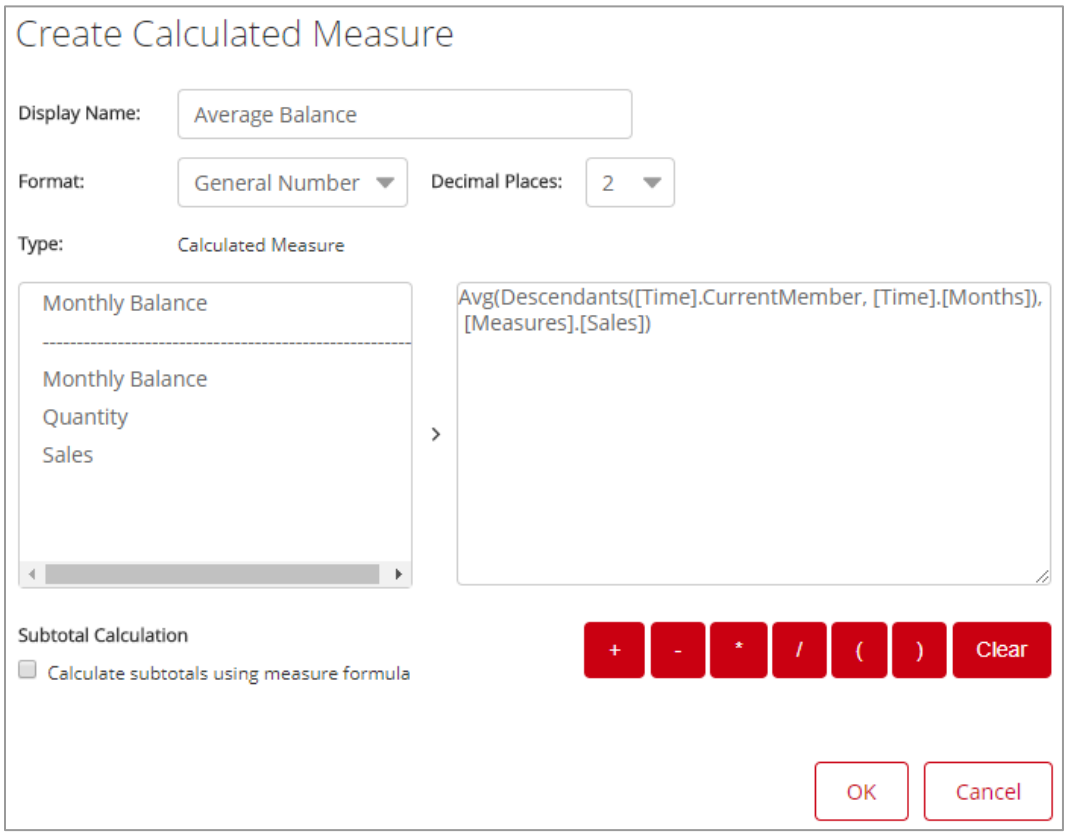


Figure 36: Creating `Average Balance` Measure

You can easily replace the `Avg` with `Min`, `Max`, `Sum`, or `Count` to get a different semi-additive behavior.

Sometimes, you might need to filter the set that goes into the semi-additive calculation. For example, if you added `Month` onto the above report, you would notice that November had much higher sales than the other months. If this is an outlier and you want to exclude that month by considering only months with balances less than 1,000000, you can achieve that with the `Filter` MDX function by creating a calculated measure using this code:

```
Avg(Filter(Descendants([Time].CurrentMember, [Time].[Months]),
[Measures].[Sales] < 1000000), [Measures].[Sales])
```

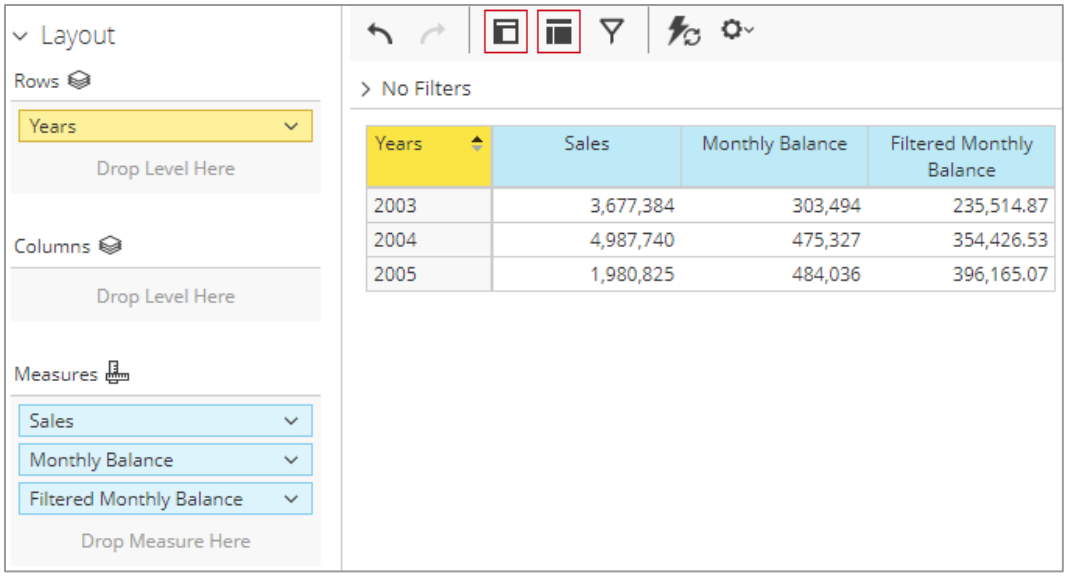


Figure 37: Monthly Balances (Filtered)

Another example of something you could do with the `Filter` MDX function is to find the first month that does have a balance, if the last month of the year does not have a balance.

Creating a Conditional Measure

A conditional measure is any measure which has `if-else` logic, like `case` statements in SQL. In this example, a user defined measure increases only `Ships` sales by 100%.

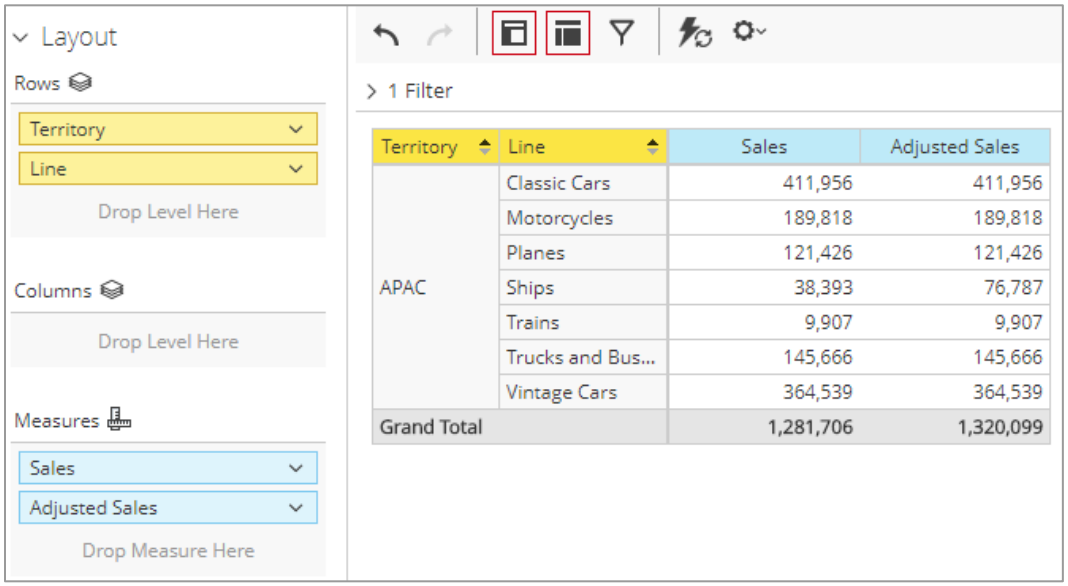


Figure 38: Conditional Measure

`Adjusted Sales` is defined as follows:

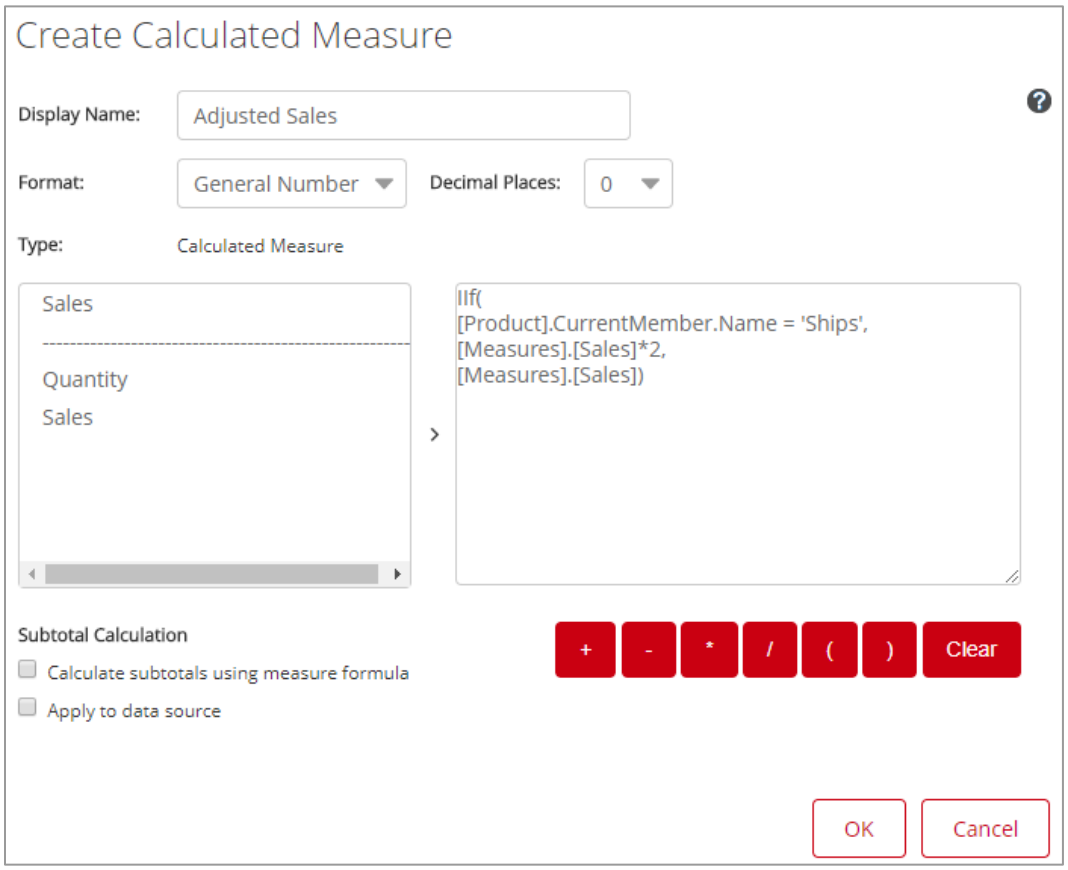


Figure 39: Adjusted Sales Measure

You can use `AND/OR` logic as well as nest the `IIF` function to create more interesting conditions.

In the above example, `Product Line` was on the report, so you could just conditionally check the current `Product Line` member.

However, if `Product Line` was not on the report, you could obtain the same results by explicitly iterating over all `Product Line` members and then applying your conditions. Create the arrows by setting the **Trend Arrow** option:

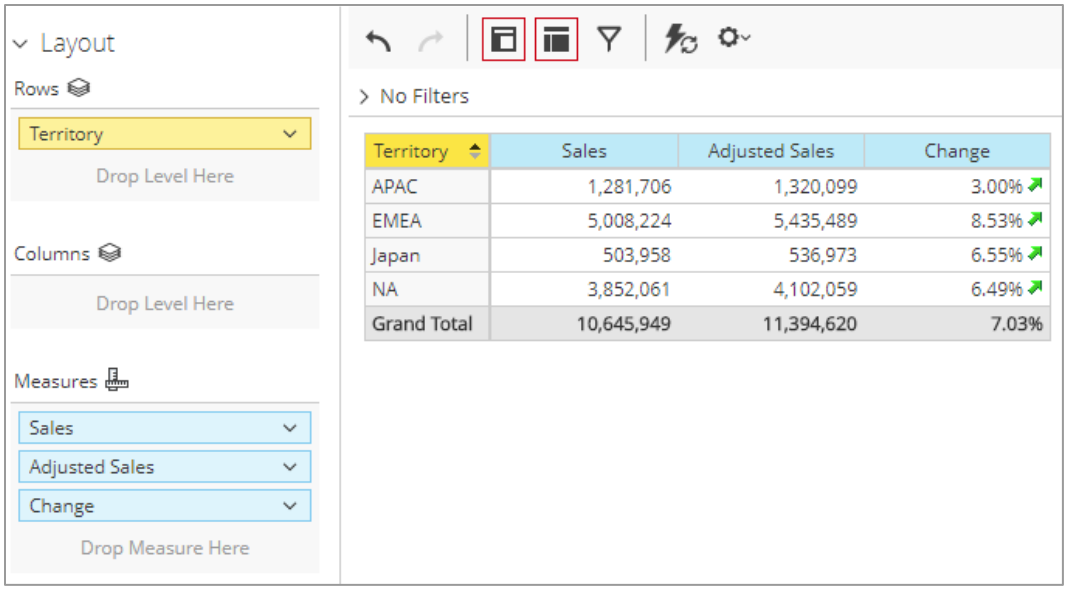


Figure 40: Trend Arrows

`Adjusted Sales` will iterate over all `Product Line` members and check to see if the current `Product Line` is `Ships`. If it is, `Adjusted Sales` will increase `sales` by 100%:

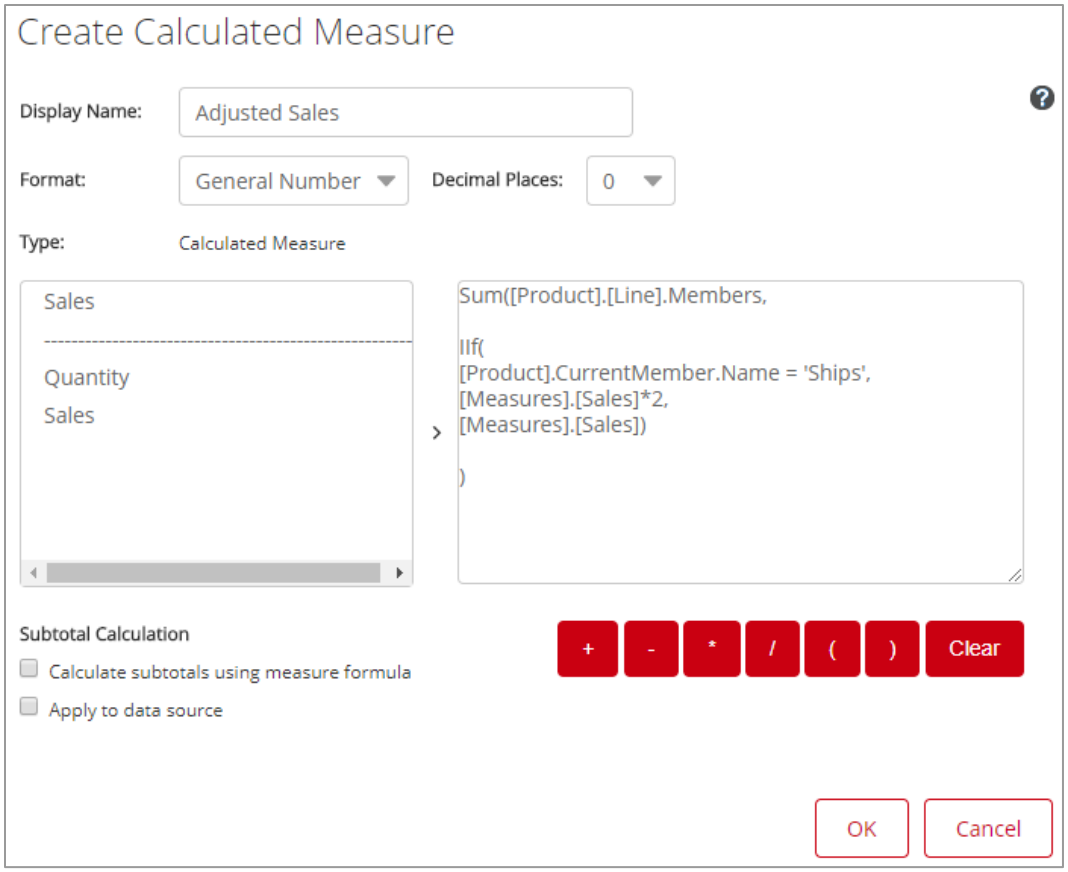


Figure 41: `Adjusted Sales` Measure Iterating over all `Product Lines`

The Change measure is just another user defined measure:

$$\left(\frac{\texttt{Adjusted Sales}}{\texttt{Sales}}\right) - 1$$

Be sure to check the **Calculate subtotals using measure formula** so that you get a ratio of sums, and not a sum of ratios.

Comparing YTD for Current and Previous Year

When looking at YTD for the current year, you may want to compare it to the YTD for the previous year.

When calculating YTD for the previous year, include only the previous year's dates up to the current year's same date.

In this example, use May 2005 YTD sales. For the YAGO YTD, add up January 2004 to May 2004, so you can make a valid YTD comparison between the two years.

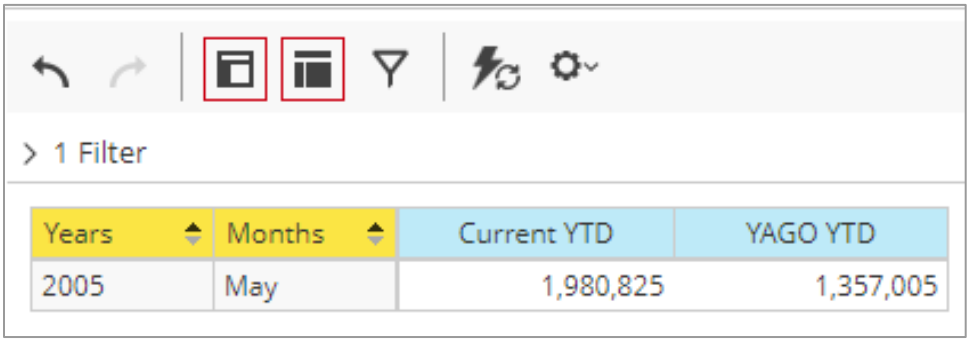


Figure 42: YAGO YTD

Set up the `Current YTD` user defined measure:

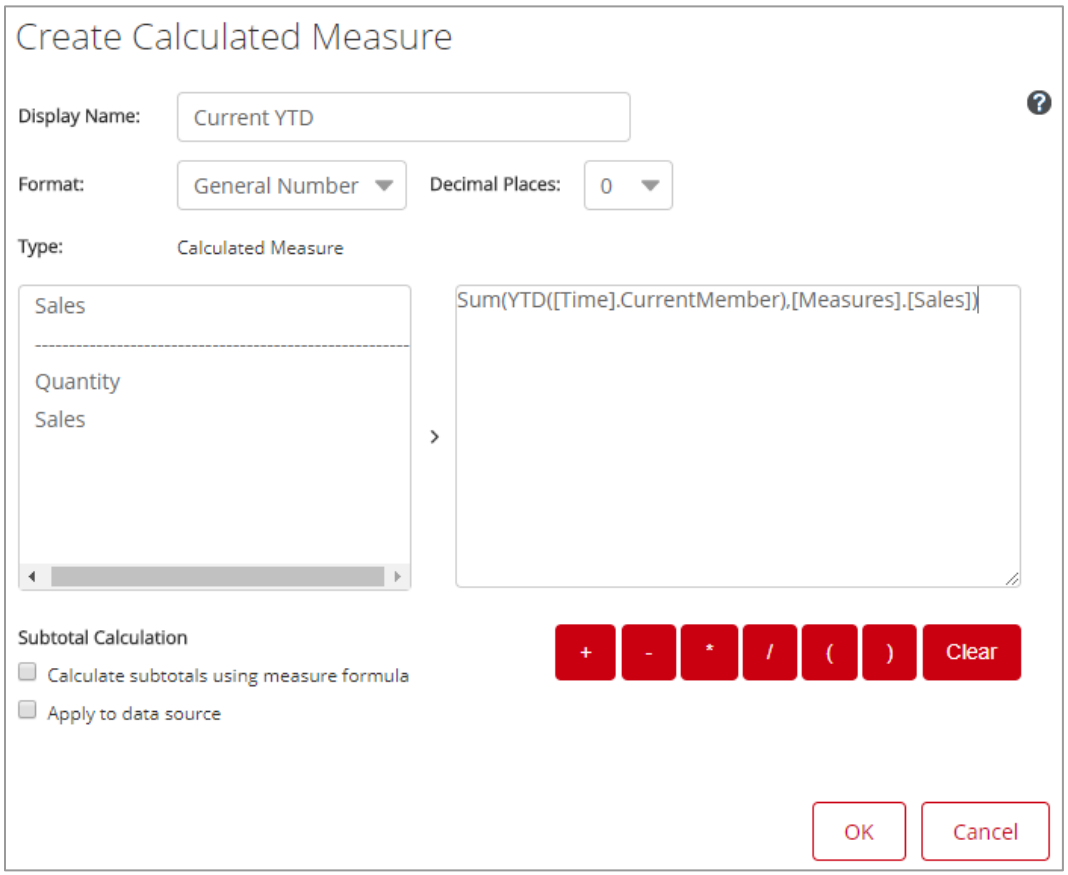


Figure 43: `Current YTD` Measure

For the `YTD`, `MTD`, `QTD`, and `WTD` functions to work, you must define the `LevelType` attribute on the `time` levels in the Mondrian schema.

You can also get the same date member by using the `PeriodsToDate` function. This expression is equivalent to the above `YTD` calculation:

```
Sum(PeriodsToDate([Time].[Years], [Time].CurrentMember),[Measures].[Sales])
```

The YAGO YTD calculation is just based on a trend measure:

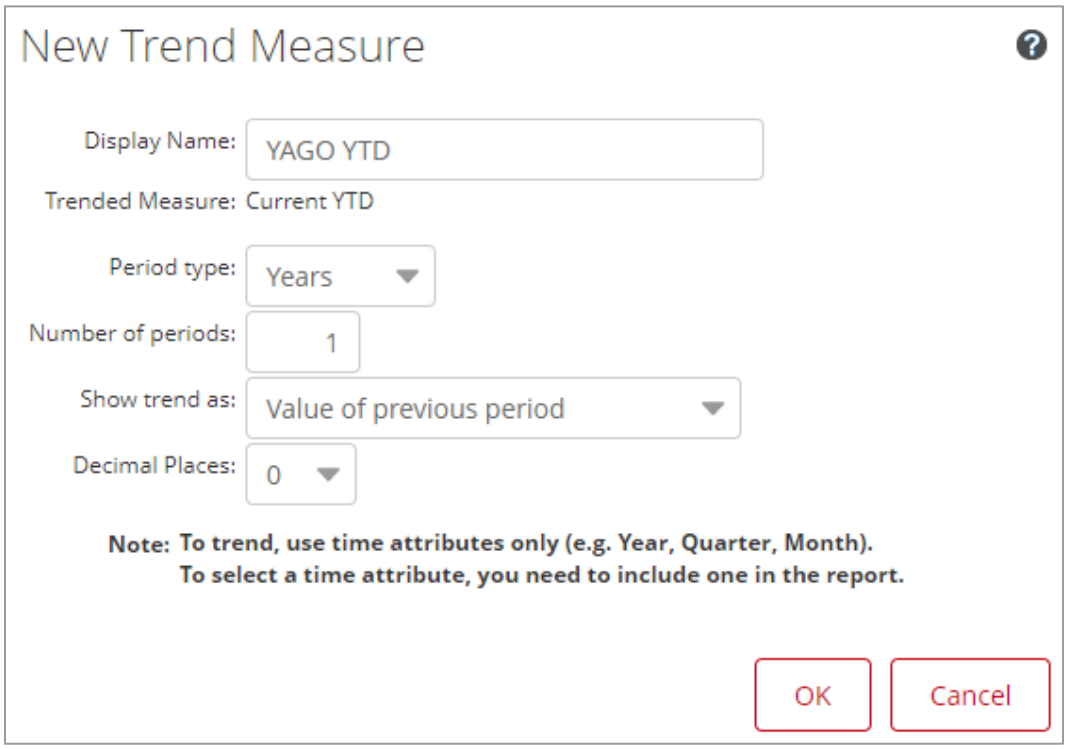


Figure 44: YAGO YTD Trend Measure

As an MDX exercise, you can also achieve the same YAGO YTD result with this MDX expression:

```
Sum(YTD(ParallelPeriod([Time].[Years],
1,[Time].CurrentMember)),[Measures].[Sales])
```

In this expression, you are using the `ParallelPeriod` function to get the same month a year ago. The `CurrentMember` refers to May 2005, and the same month one year ago would be May 2004.

Generating Trend Lines Using Linear Regression

You can add trend lines to a line chart by fitting a line to your data. For example, this chart shows the least squares regression of `Sales` on `Months`:

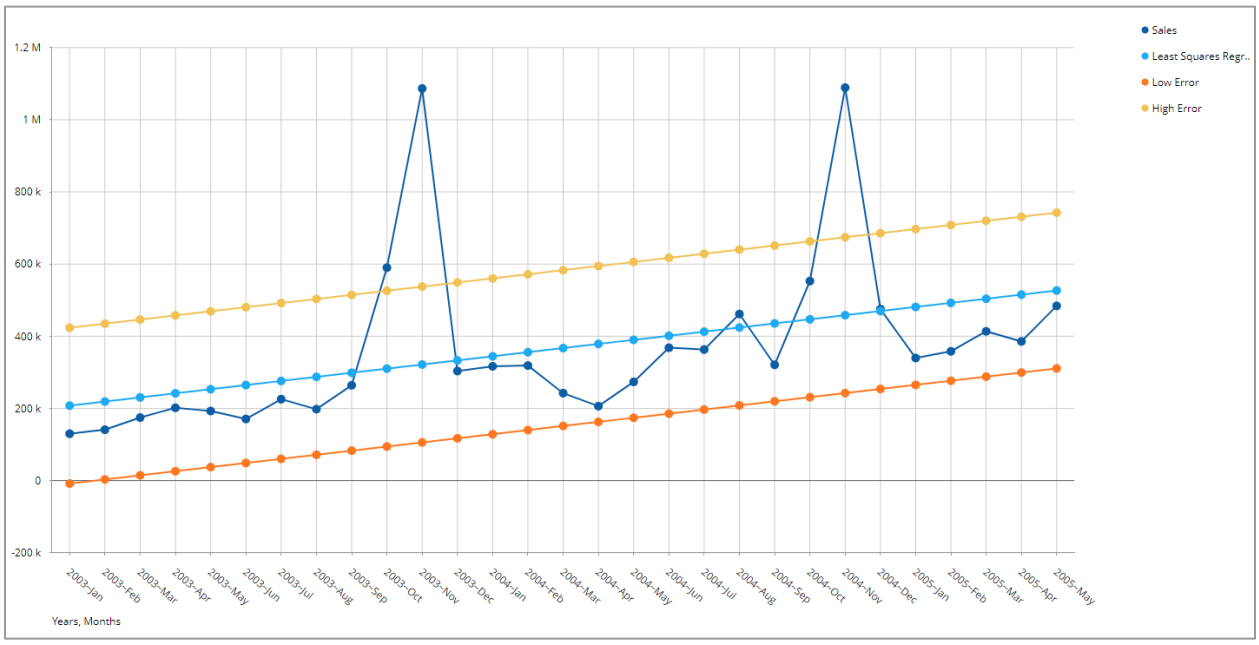


Figure 45: Least Squares Regression of `Sales` on `Months`

The `Sales` measure is the actual sales amount in each month. A least squares regression uses the `LinRegPoint` function to predict `Sales`, given the explanatory variable `Month`.

You can also calculate residuals and the standard error of regression, which is the standard deviation of the residuals. Because these residuals have a bell-shaped distribution around the fitted line, you can infer that two-thirds of the actual sales were within +/- one standard deviation of the fitted line. This +/- boundary is marked by the `High` and `Low Error` lines.

Here is the underlying data for the chart:

Years	Months	Sales	Least Squares Regression	Residuals	Standard Error of Regression	Low Error	High Error
2003	Jan	129,754	207,541	-77,787	215,940	-8,399	423,481
	Feb	140,836	218,938	-78,102	215,940	2,998	434,879
	Mar	174,505	230,335	-55,831	215,940	14,395	446,276
	Apr	201,610	241,733	-40,123	215,940	25,792	457,673
	May	192,673	253,130	-60,457	215,940	37,190	469,070
	Jun	170,559	264,527	-93,968	215,940	48,587	480,467
	Jul	225,486	275,924	-50,438	215,940	59,984	491,864
	Aug	197,809	287,321	-89,512	215,940	71,381	503,262
	Sep	263,973	298,719	-34,745	215,940	82,778	514,659
	Oct	589,964	310,116	279,848	215,940	94,176	526,056
	Nov	1,086,720	321,513	765,207	215,940	105,573	537,453
	Dec	303,494	332,910	-29,416	215,940	116,970	548,850
2004	Jan	316,577	344,307	-27,730	215,940	128,367	560,248
	Feb	318,699	355,705	-37,006	215,940	139,764	571,645
	Mar	242,143	367,102	-124,959	215,940	151,161	583,042
	Apr	206,148	378,499	-172,351	215,940	162,559	594,439
	May	273,438	389,896	-116,458	215,940	173,956	605,836
	Jun	368,127	401,293	-33,166	215,940	185,353	617,233
	Jul	363,056	412,690	-49,635	215,940	196,750	628,631
	Aug	461,501	424,088	37,414	215,940	208,147	640,028
	Sep	320,751	435,485	-114,734	215,940	219,545	651,425
	Oct	552,924	446,882	106,042	215,940	230,942	662,822
	Nov	1,089,048	458,279	630,769	215,940	242,339	674,219
	Dec	475,327	469,676	5,650	215,940	253,736	685,617
2005	Jan	339,543	481,074	-141,530	215,940	265,133	697,014
	Feb	358,186	492,471	-134,285	215,940	276,530	708,411
	Mar	413,531	503,868	-90,337	215,940	287,928	719,808
	Apr	385,529	515,265	-129,736	215,940	299,325	731,205
	May	484,036	526,662	-42,626	215,940	310,722	742,603

Figure 46: Data for `Least Squares Regression`

Create `Least Squares Regression` as a user defined measure:

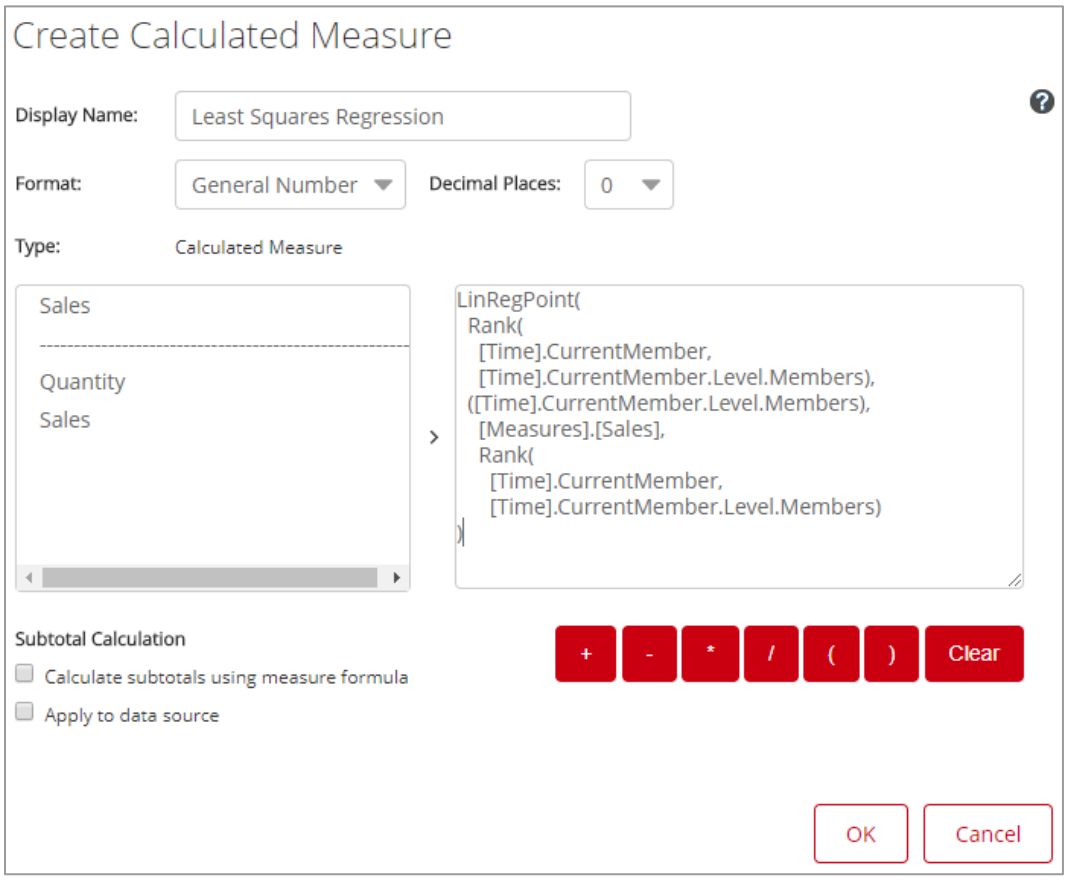


Figure 47: Defining `Least Squares Regression`

Calculate `Residuals` with this MDX expression:

```
[Measures].[Sales]-[Least Squares Regression]
```

Calculate the `Standard Error of Regression`:

```
Power(
Sum([Time].CurrentMember.Level.Members, Power([Residuals], 2))
/  (Count([Time].CurrentMember.Level.Members)-2)
, .5)
```

Calculate `Low Error` with this MDX expression:

```
[Least Squares Regression]-[Standard Error of Regression]
```

Calculate `High Error` with this MDX expression:

```
[Least Squares Regression]+[Standard Error of Regression]
```

Conditionally Highlighting or Formatting Cells

You can conditionally format cells based on the measure value or the current dimension members intersecting on the current cell, using an MDX format expression.

In the next report, color cells based on the following rules:

- `Sales` < `250,000` then color `Red`
- `Sales` < `1,250,000` then color `Yellow`
- `Sales` > `4,000,000` then color `Green`

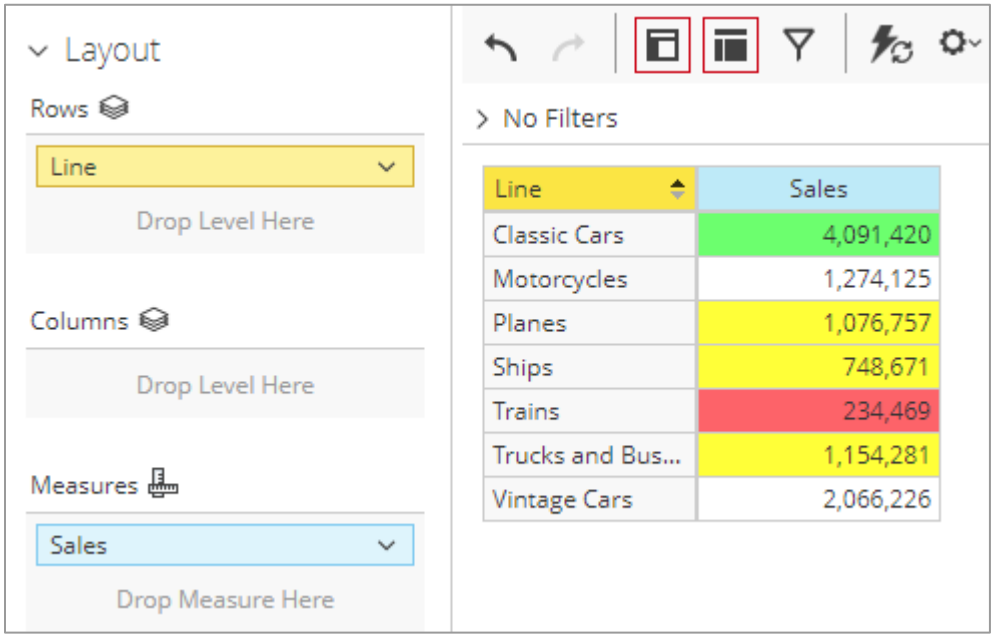


Figure 48: Line and Sales

Define the MDX expression as follows:

```
Case
When [Measures].CurrentMember < 250000
Then '|#,##0|style=red'
When [Measures].CurrentMember < 1250000
Then '|#,##0|style=yellow'
When [Measures].CurrentMember > 4000000
Then '|#,##0|style=green'
Else '|#,##0'
End
```

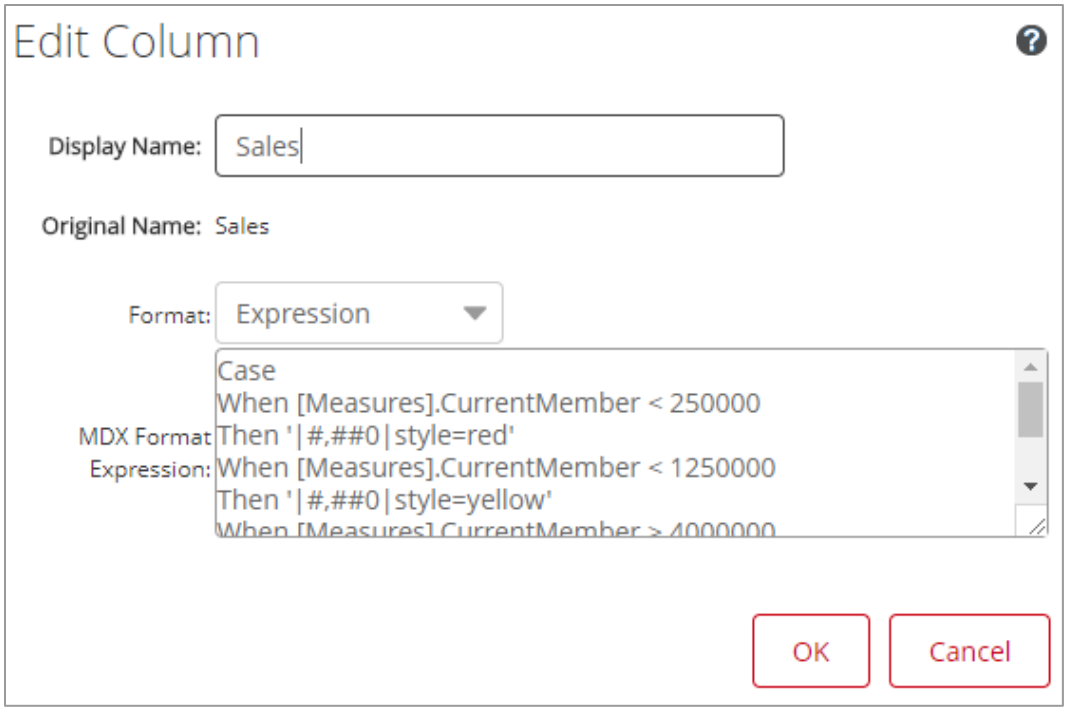


Figure 49: Defining Format Expression

The `Case` MDX expression must return a valid format string such as:

`|#,##0|style=red`

Here are some useful format strings:

- `General Number: #,##0.0`
- `Currency: $#,##0.00`
- `Percentage: ###0.00%`

Analyzer supports the following additional formatting properties:

- `style=red|yellow|green` - Highlights the cell with the given color. Only these three colors are supported.
- `image=icon.gif` – Shows an icon in the cell next to the cell value. This icon must be placed in `system/analyzer/images/report/`.
- `arrow=up|down|none` – Shows an up arrow/down arrow next to the cell value.
- `link=http://www.pentaho.com` – Makes the cell value a hyperlink which opens the indicated URL.
- `color=#FFFFFF` – Sets the background color using an RGB color in Hex value.

Here is an example of how this additional formatting could look:

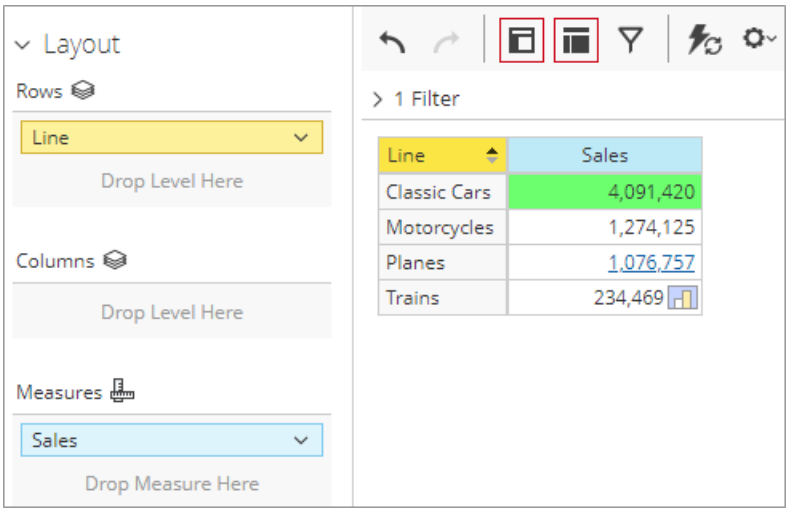


Figure 50: Additional Formatting

By referencing the dimension members on the current evaluation context of the cell, you can also parameterize the format expressions.

For example, you could use an expression to create a link to search on the customer's address, which is exposed as a `Customer` member property.

The format MDX expression for `Sales` would then look like:

```
'|#,##0|link="https://www.google.com/search?q='||[Customers].CurrentMember.
Properties("Address")||'"'
```

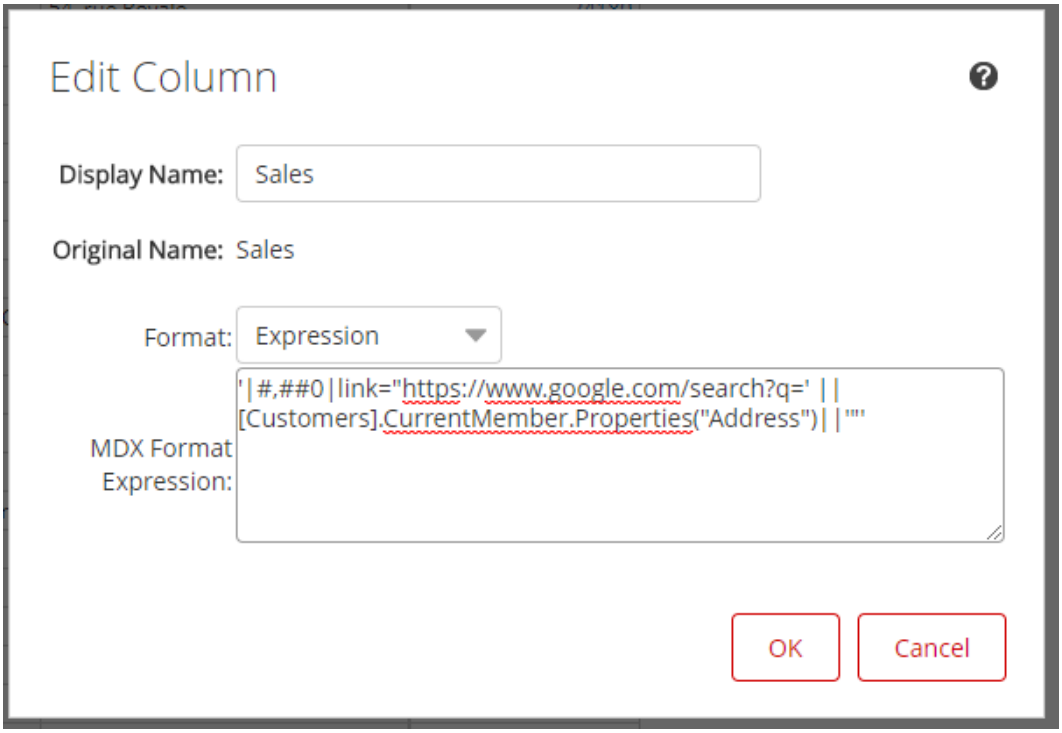
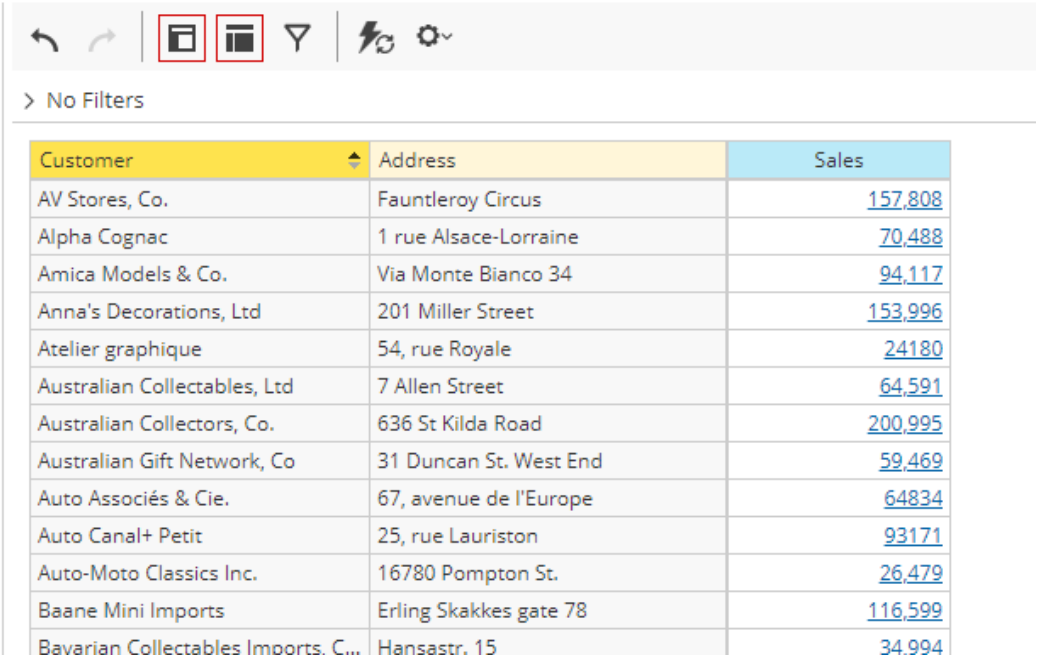


Figure 51: Customer Address Query

Results would resemble this:



> No Filters

Customer	Address	Sales
AV Stores, Co.	Fauntleroy Circus	157,808
Alpha Cognac	1 rue Alsace-Lorraine	70,488
Amica Models & Co.	Via Monte Bianco 34	94,117
Anna's Decorations, Ltd	201 Miller Street	153,996
Atelier graphique	54, rue Royale	24180
Australian Collectables, Ltd	7 Allen Street	64,591
Australian Collectors, Co.	636 St Kilda Road	200,995
Australian Gift Network, Co	31 Duncan St. West End	59,469
Auto Associés & Cie.	67, avenue de l'Europe	64834
Auto Canal+ Petit	25, rue Lauriston	93171
Auto-Moto Classics Inc.	16780 Pompton St.	26,479
Baane Mini Imports	Erling Skakkes gate 78	116,599
Bavarian Collectables Imports, C...	Hansastr. 15	34,994

Figure 52: Customer Address Search

There are a few more things to note:

- The MDX format expression is first evaluated on the current cell which includes the measure and all dimension members that intersect on the cell.
- You can use `IIF` and `CASE MDX` functions to conditionally return a format string.
- The format string is used to format the cell value. If the formatted value takes the form of: `<formatted value>|<property name>=<property value>`, additional formatting such as the background color or hyperlink is added to the formatted value.
- Use single quotes to escape string literals in the MDX expression.
- Use double quotes to escape string literals in the format string.
- A double quote is used within the single quoted string literal to escape the double quoted string literal within the format string. In the above example, this saves you the trouble of having to escape special formatting characters in the `Address` member property.
- `||` is used to concatenate strings in MDX expressions
- Refer to Mondrian documentation for more MDX functions.
- Refer to MSDN documentation for more information on constructing format strings.

Filtering on a Member Property

Members in a level can have additional member properties such as product codes or IDs. Normally, you cannot filter directly on these member properties, since these properties do not show up as fields. However, you can work around this by creating a user defined measure that uses the `Properties` MDX function to retrieve a member property and then filter on it.

In this example, filter on the `Product Code` member property to include only products with codes that start with S18:

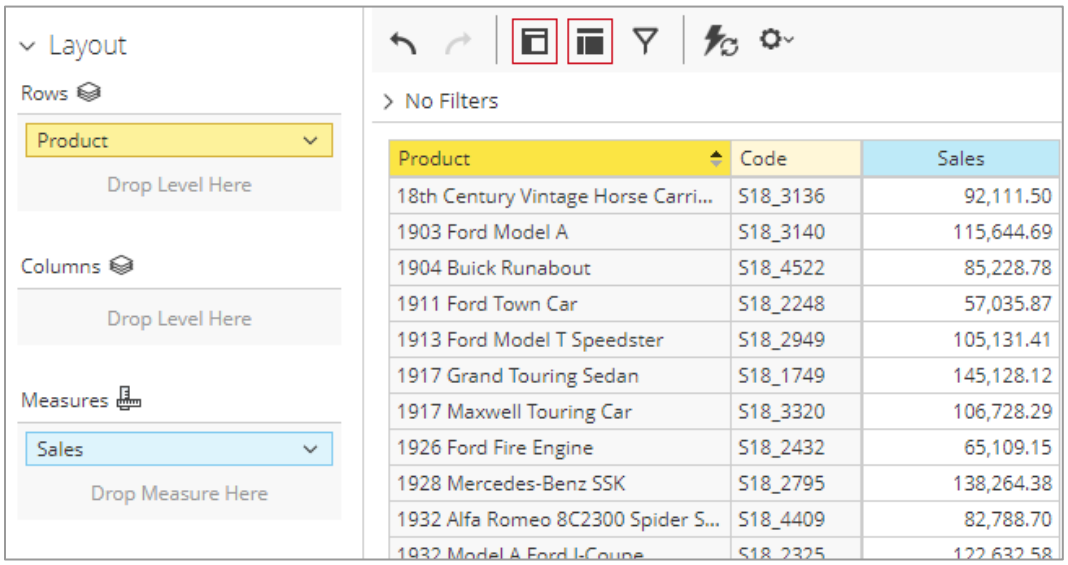


Figure 53: Filtering on `Product Code`

Create the user defined measure `Sales` as follows:

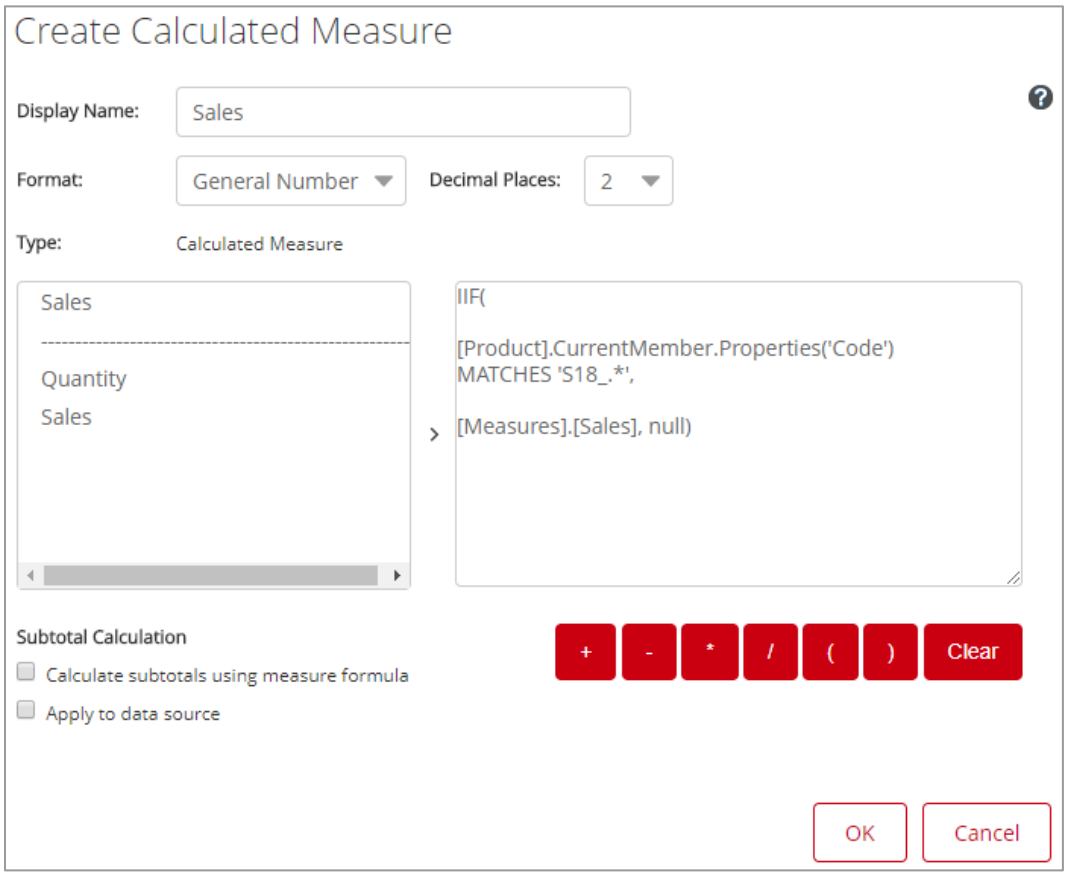


Figure 54: Measure for Finding Specific Product Codes

The `MATCHES` MDX function is a Mondrian-specific function that uses a Java regular expression. Notice that when the filter does not match, `null` is returned. Since the report does not show `null` cells, those products that don't meet this filter will not be shown on the report. Note also that the `Grand Total` will be computed correctly.

Adding Target or Goal Measures to a Report

Often, you want to compare actual versus previously set targets or goals. These goals may be stored directly in the report so that you can monitor the `% Completion` over time:

Territory	Sales	Goal	% Completion
APAC	1,281,706	2,000,000	64.1%
EMEA	5,008,224	6,000,000	83.5%
Japan	503,958	1,000,000	50.4%
NA	3,852,061	3,000,000	128.4%
Grand Total	10,645,949	12,000,000	-

Figure 55: `% Completion` Over Time

The `Goal` measure is just a user defined measure that checks each `Territory` member and assigns a `goal` value.

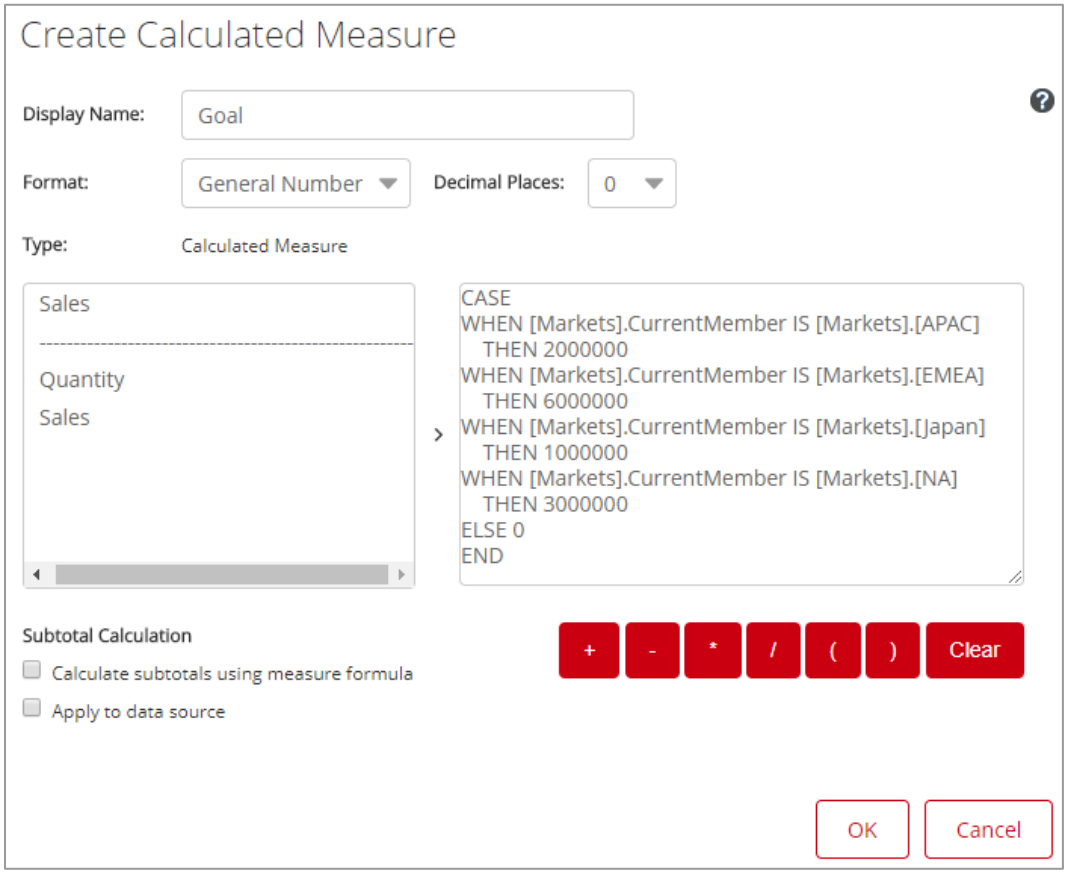


Figure 56: Goal Measure

The `% Completion` is another user defined measure with the following MDX expression:

```
[Measures].[Sales]/[Measures].[Goal]
```

You can achieve the colored highlighting with the following format MDX expression:

```
Case
When [Measures].CurrentMember < .6
Then '|#,##0.0%|style=red'
When [Measures].CurrentMember < .8
Then '|#,##0.0%|style=yellow'
When [Measures].CurrentMember > 1
Then '|#,##0.0%|style=green'
Else '|#,##0.0%'
End
```

Calculating a Weighted Average

A weighted average is useful in calculating an average unit price that considers the quantity of each transaction at a given price. In this next example, `Sales` is the unit price paid by each customer for the 1928 Mercedes-Benz SSK.

Product	Customer	Sales	Quantity	Weighted Average
1928 Mercedes-Benz S...	AV Stores, Co.	$6,338.47	55	$8,350.67
	Amica Models & Co.	$4,455.00	22	$8,350.67
	Australian Collectables, Ltd	$3,675.32	22	$8,350.67
	Australian Collectors, Co.	$11,298.76	55	$8,350.67
	Auto Associés & Cie.	$3,577.60	20	$8,350.67
	Blauer See Auto, Co.	$3,773.38	26	$8,350.67
	Corporate Gift Ideas Co.	$7,209.12	48	$8,350.67
	Corrida Auto Replicas, Ltd	$9,534.50	50	$8,350.67
	Euro+ Shopping Channel	$14,433.52	104	$8,350.67
	Extreme Desk Decorations, L...	$5,315.80	35	$8,350.67
	GiftsForHim.com	$7,749.28	56	$8,350.67
	Herkku Gifts	$8,272.34	43	$8,350.67
	Lyon Souveniers	$4,462.20	30	$8,350.67
	Mini Caravy	$3,726.00	24	$8,350.67
	Mini Gifts Distributors Ltd.	$14,393.59	107	$8,350.67
	Online Diecast Creations Co.	$5,797.44	36	$8,350.67
	Rovelli Gifts	$3,452.68	22	$8,350.67
	Saveley & Henriot, Co.	$5,579.02	29	$8,350.67
	Signal Collectibles Ltd.	$4,230.62	23	$8,350.67
	Souveniers And Things Co.	$7,956.46	41	$8,350.67
	Toys4GrownUps.com	$3,033.28	32	$8,350.67
1928 Mercedes-Benz SSK Sum		-	880	-
1928 Mercedes-Benz SSK Average		$6,584.02	-	$8,350.67

Figure 57: `Weighted Average` Results

The average price paid as shown in the `Sales` total is `$6,584.02`. However, this is just a straight average that does not consider that some customers such as `Euro+ Shopping Channel` and `Mini Gifts Distributors, Ltd`. purchased higher quantities at much higher prices. The `Weighted Average` measure will weigh the unit sale price by the quantities purchased at each price.

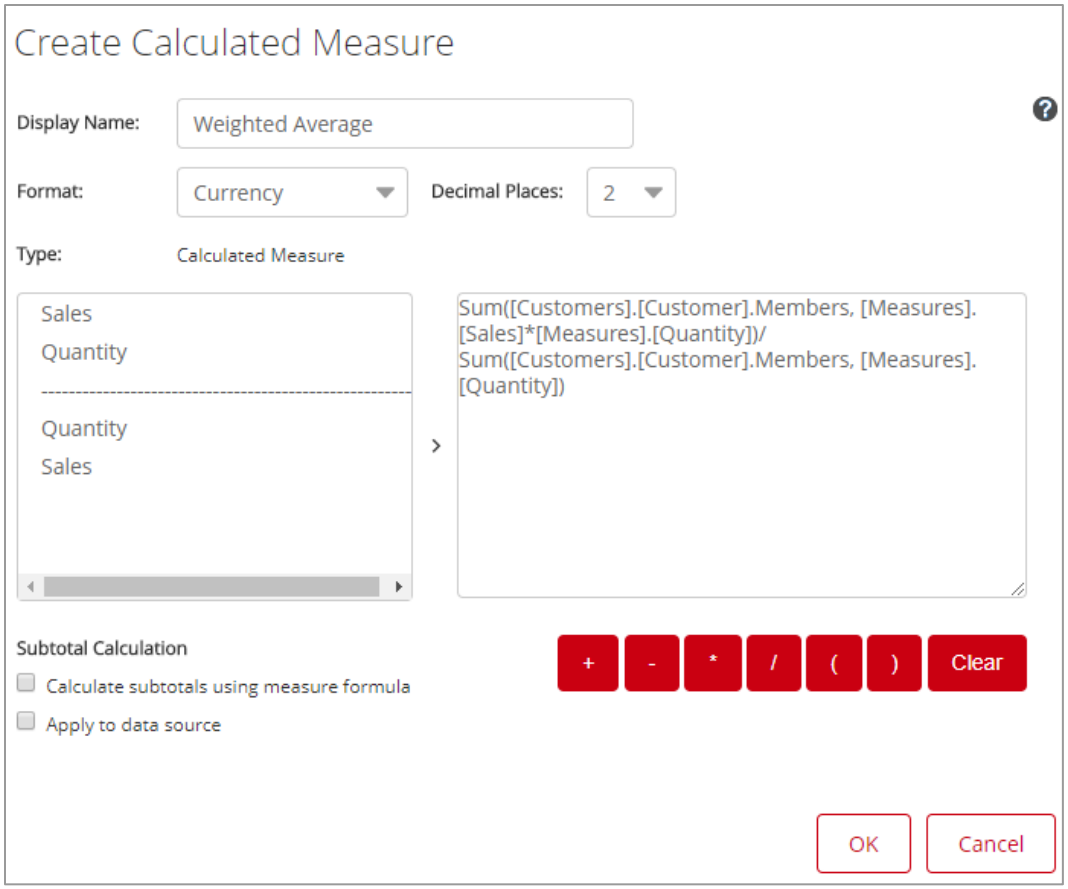


Figure 58: `Weighted Average` Measure

When dealing with many transaction records, it is more efficient for you to do the calculation in the database, rather than in Mondrian. Define a relational measure which returns the sum of `Sales * Quantity` and another relational measure which returns the sum of `Quantity`, then create a calculated measure to divide the two.

How Solve Orders Affect Calculating Measures

Solve orders determine the order of calculations when there are competing calculated members on a single cell. MSDN has a detailed explanation with a working example at [MDX Data Manipulation – Understanding Pass Order and Solve Order](#).

Here is another example to help you understand solve orders in Analyzer:

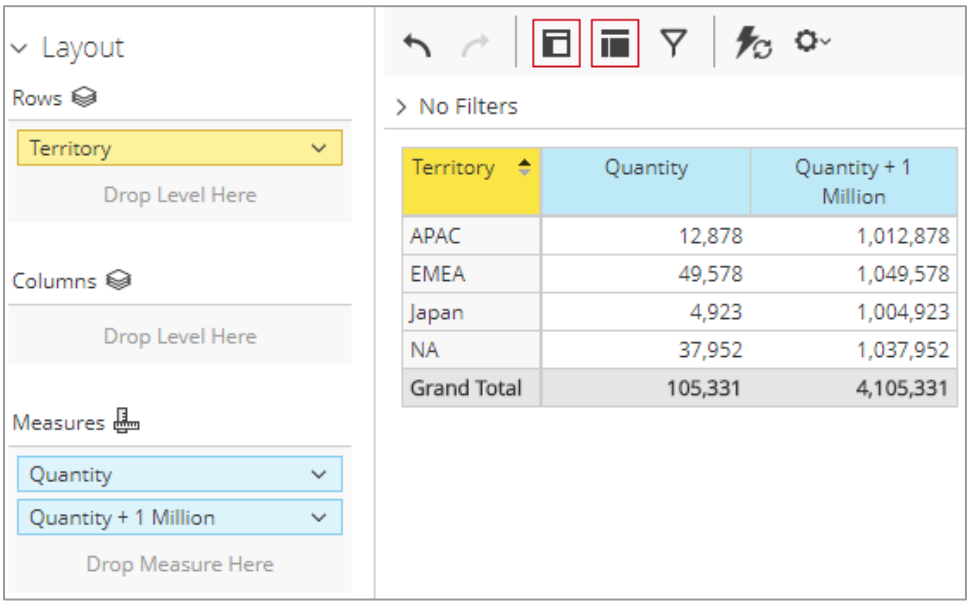


Figure 59: `Quantity + 1 Million`

Create `Quantity + 1 Million` with a user defined measure:

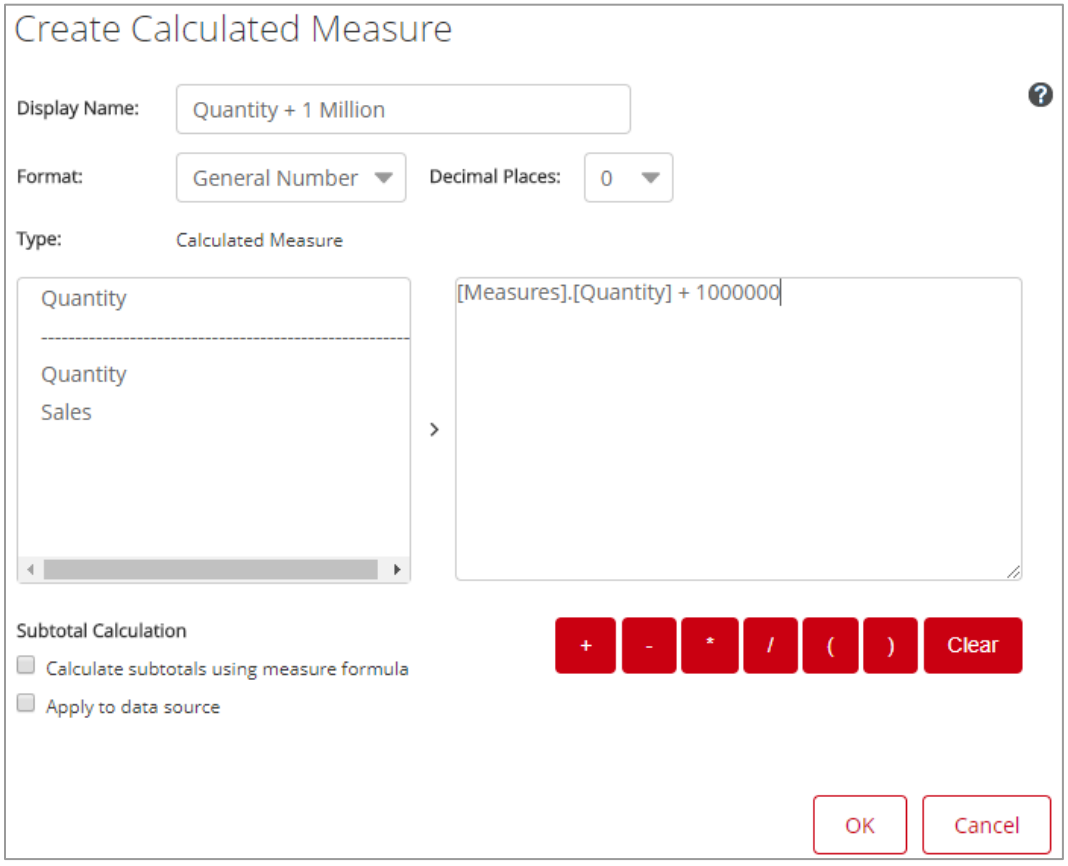


Figure 60: `Quantity + 1 Million` Calculated Measure

The `Grand Total` in the `Quantity + 1 Million` column has two competing calculated members, listed below with their corresponding MDX as grabbed from the log file:

`Quantity + 1 Million` → `Solve Order = 0`

```
MDX: MEMBER [Measures].[*CALCULATED_MEASURE_0] AS
'[Measures].[Quantity]+1000000', FORMAT_STRING = '#,##0', SOLVE_ORDER=0
```

`Grand Total` → `Solve Order = 100`

```
MDX: MEMBER [Markets].[*TOTAL_MEMBER_SEL~SUM] AS 'SUM([*NATIVE_CJ_SET])',
SOLVE_ORDER=100
```

Since `Grand Total` has a higher solve order than `Quantity + 1 Million`, the bottom right cell will be calculated by iterating over each `Territory` and then summing up the `Quantity` + 1,000,000.

Now, if you go back to the same report and check the **Calculate subtotals using measure formula** box in the calculated measure, the `Quantity + 1 Million`'s solve order will be changed from `0` to `200`.

In this case, because `Quantity + 1 Million` has a higher solve order than `Grand Total`, the bottom right cell will now be calculated by adding 1,000,000 to the sum of each `Territory`'s `Quantity`:

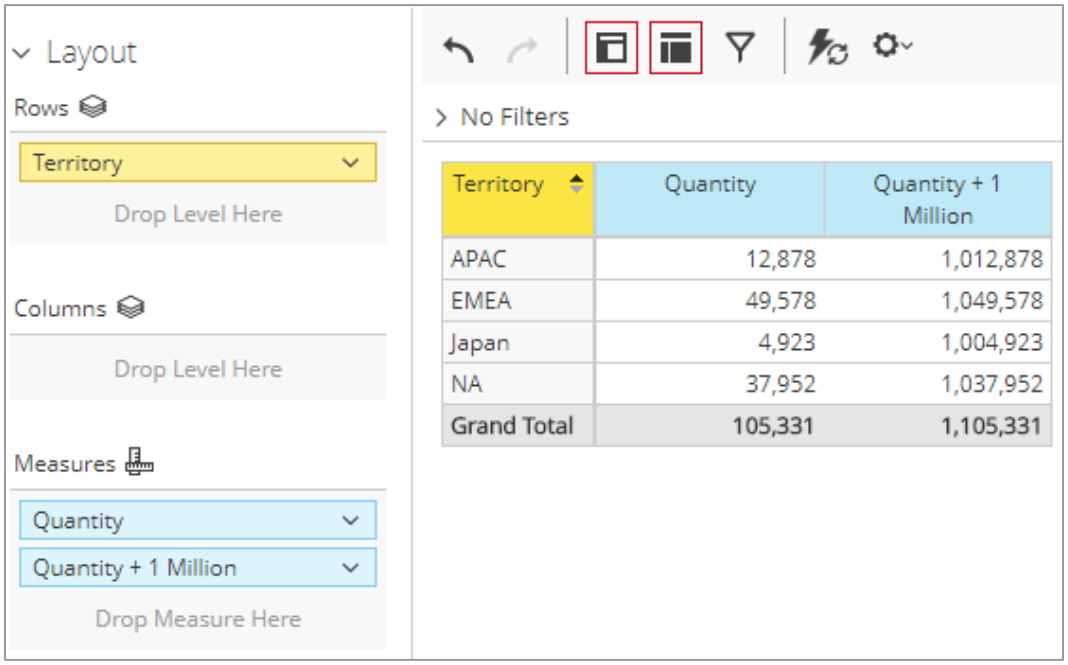


Figure 61: Calculating `Quantity + 1 Million` Using Measure Formula

By default, all schema defined measures will have a solve order of `0`. You can override this for calculated measures by setting the `CalculatedMemberProperty SOLVE_ORDER`:

```
<CalculatedMember name="Average Sales Price" dimension="Measures">
   <Formula>[Measures].[Sales]/[Measures].[Quantity]</Formula>
   <CalculatedMemberProperty name="FORMAT_STRING" value="$#,##0.00" />
   <CalculatedMemberProperty name="SOLVE_ORDER"
value="200"></CalculatedMemberProperty>
</CalculatedMember>
</Cube>
```

For reference, here are the solve orders that Analyzer uses for different types of calculated members:

Table 2: Solve Orders for Analyzer

Calculated Member	Solve Order	Purpose
Formatting	500	Used to apply a format string
Numeric Filters	400	Used to apply context for Top N, Greater Than, and Similar filters
Min, Max, Count, and Average Totals	300	Used for subtotals
"Smart" Measures	200	Used when Calculate subtotal using formula is checked
Sum Totals	100	Used for subtotals
Aggregate Totals	-100	Used for subtotals
Trend Hangar	-200	Used to apply context for trend user defined measures
Slicer	-300	Used to apply slicer filters

Test Your MDX Knowledge

This is the answer to the quiz question in the Core Recipe Learning MDX:

```
WITH
MEMBER [Measures].[% of Total] AS
'[Measures].[Sales]/([Measures].[Sales],Ancestor([Markets].CurrentMember,
[Markets].[Territory]))', FORMAT_STRING = '###0.00%'
SELECT
{[Measures].[Sales], [Measures].[% of Total]} ON COLUMNS,
UNION({[Markets].[All Markets].[NA]},[Markets].[NA].Children) ON ROWS
FROM [SteelWheelsSales]
```

The answer is highlighted in red. Here, you used the `Ancestor` MDX function to find the ancestor member at the `Territory` level. For USA and Canada, this works fine and returns NA. However, for NA, since it is already at the `Territory` level, the Ancestor function just returns NA again. This type of measure is also known as a level based measure, described in Pinning a Measure to a Specific Hierarchy Level.

Related Information

Here are some links to information that you may find helpful while using this best practices document:

- Java regular expressions
- Julian Hyde's blog entry on `CurrentDateMember`
- MDX Data Manipulation – Understanding Pass Order and Solve Order
- MSDN
- Pentaho: Enable Relative Date Filters in Mondrian
- Pentaho: Mondrian documentation