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Enhancing Forecasting Capability of Excel with User Defined Functions

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Keywords

Forecasting, Exponential Smoothing, User Defined Function, UDF

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Cover Page Footnote

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Enhancing Forecasting Capability of Excel with User Defined Functions

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Abstract

We have developed seven user defined functions (UDF) related to forecasting. The first four functions are for exponential smoothing. These are simple exponential smoothing, Holt's fit, Winter's method and Holt-Winter method. The next three functions can be used to calculate forecasting errors. These errors are mean square error (MSE), mean absolute difference (MAD) and mean absolute percentage error (MAPE). These UDFs eliminate the need for intermediate steps in exponential smoothing and error calculations. These functions are as easy to use as other forecast related (statistical) functions, such as "Trend" and "Correl". Moreover, our functions present users with choices. They can choose to provide (or not to provide) initial values and seasonal indices (where applicable). These characteristics make our functions user-friendly and flexible, and therefore enhance the power and usefulness of excel for forecasting.

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1 Introduction

Excel's formulas and functions relieve students (and managers) from the need to use complicated mathematics to analyze and solve numerical problems [7]. Experts argue that many mathematical models and solutions are further constrained by idealistic assumptions (such as linear relationships) making their usefulness very limited [2, 4]. On the other hand, Excel can also be used to get answers for what-if questions as well as various kinds of scenario analyses and simulations [1, 7]. Simple macros and functions can be used to customize Excel for a particular use. It also greatly enhances Excel's capability to experiment and simulate. Students and decision-makers who require data analysis greatly benefit from this enhanced capability [1, 5].

This article focuses on user defined functions (UDFs) for forecasting. Excel has many functions (built-in as well as in the data analysis add-in) related to forecasting [6]. However, practitioners and academics use varieties of forecasting models (such as Winter's or Holt-Winter's model) which cannot be solved directly by using these available functions only [5, 7, 9]. Here we use the VBA (Visual Basic for Applications) program to develop UDFs, to solve these models. Besides, other UDFs are also developed here for various error measurements in forecasts. UDFs and VBA are discussed in various business [for example 1, 5], as well as computer programming [for example 3, 8] books.

1.1 Forecasting Models

We have developed four functions (UDFs) for exponential smoothing and three for error measurement. In the following paragraphs these forecasting models are

briefly discussed, as a background to the introduction and discussion of the functions we have developed. Readers interested in detail descriptions of this topic are directed to relevant text books [for example 7, 9].

2 Exponential Smoothing

2.1 Simple Exponential Smoothing

Simple exponential smoothing is used when data do not have underlying trend and seasonality and are mostly stationary. The formula for exponential smoothing methods is $S_t = S_{t-1} + \alpha(A_t - S_{t-1})$; where, S_t and S_{t-1} are the smoothed estimates in periods t and $t - 1$ respectively, and A_t is actual data in period t and α is the smoothing constant, whose value can be from 0 to 1.

The smoothed estimate is equal to old estimate plus some adjustment. The size of adjustment depends on the size of the error and the value of α . Error is the difference between the actual data and the smoothed estimate. The estimate for any future period is equal to the smoothed estimate.

2.2 Winter's Method

Winter's Method is used when the underlying data have seasonality, but no trend. The number of seasons and seasonal indices vary from case to case. Yet, the total of all seasonality indices should be equal to the number of seasons. For example if there are four seasons, the total should be equal to four.

In this case smoothed value and seasonal index must be estimated. The formula for estimating smoothed value is $S_t = S_{t-1} + \alpha(A_t/I_L - S_{t-1})$, where, I_L is the appropriate index for the given season. In addition, seasonal indices have to be revised. The estimate of new value for seasonal index is $I_{LN} = I_L + \gamma(A_t/I_L - S_{t-1})$ and, the forecast for period t is $F_t = S_t I_L$.

In this case, α and γ are two smoothing constants whose values should be between zero and one. Here, the smoothed parameter and seasonal index are estimated by adjusting to their respective old estimates. The adjustments depend on the size of error and the values of appropriate smoothing constants (α or γ).

2.3 Exponential Smoothing with Trend (Holt's Fit)

Holt's Fit is used when the underlying data shows trend but not seasonality. The formula for estimating smoothed value is $S_t = S_{t-1} + T_{t-1} + \alpha(A_t + (S_{t-1} + T_{t-1}))$, where T_{t-1} is the trend of the period $t - 1$. Similarly, the formula for trend estimate is $T_t = T_{t-1} + \beta(S_t - S_{t-1} + T_{t-1})$ and the forecast for period n is $F_n = S_t + nT_t$, where n is the number of periods after the last available data. If there are data for 10 periods and the forecast is to be done for 12th period then $n = 2$.

In this case, α and β are two smoothing constants whose values should be between zero and one. As shown above, the smoothed parameter and trend are estimated by adjusting to their respective old estimates. These adjustments depend on the sizes of errors and the values of the appropriate smoothing constants (α or β).

2.4 Exponential Smoothing with Trend and Seasonality (Holt-Winter Method)

For this case, the underlying data should have both trend and seasonality. There are three estimates in this case; one for the smoothed value, the second for trend and the third for seasonality.

Here, the smoothed estimate is $S_t = S_{t-1} + T_{t-1} + a \left(\frac{A_t}{I_L} - (S_{t-1} + T_{t-1}) \right)$

Similarly, the trend estimate is $T_t = T_{t-1} + \beta(S_t - S_{t-1} + T_{t-1})$ and the seasonal index estimate is $I_{LN} = I_L + \gamma(A_t/S_t - I_L)$, The forecast for the period n is $F_n = (S_t + nT_t)I_L$, where n is the number of periods after the last available data.

α, β and γ are three smoothing constants whose values should be between zero and one. Here the smoothed parameter, trend and seasonality index are estimated by adjusting to their respective old estimates. As in other cases, the adjustments here also depend on the sizes of errors and the values of appropriate smoothing constants (α, β or γ).

2.5 Error Estimates

Any forecast is bound to have error. An error is the difference between the actual and forecasted value. Error can be measured when both the actual value and the forecasted value are available. Since errors can change from one point to the next, the mean of such errors are taken as the indicator of the accuracy of forecast. There are many ways to measure the mean of errors. However, we have confined our discussions to three such measures.

Mean Square Error (MSE): This is the mean of square of errors, where error (for the period “ t ”) is the difference between the actual value and the forecasted value in that period.

Mean Absolute Difference (MAD): The absolute difference is the absolute value of the difference between the actual value and the forecasted value. MAD is the mean of these absolute differences.

Mean Absolute Percentage Error (MAPE): Absolute percentage error is the percentage of absolute difference compared to the actual value. Mean absolute error is the mean of all the absolute percentage errors.

3 Advantages of UDFs

It is not an absolute necessity that we need functions developed here to forecast. However, these functions enhance the power and user-friendliness of the spreadsheet. In the following sections we discuss some of the advantages.

3.1 Simplicity

The role of any function is to simplify calculation so the users can focus on understanding and interpreting the result. All seven UDFs developed here simplify calculations. Users just need to select the right inputs. The functions developed here are not unlike Excel functions of “Trend” or “Correl”. Without these functions, few

intermediate steps are needed for calculating the exponential smoothing and the error measures discussed.

3.2 Flexibility

Forecasted values depend on the choice of smoothing constants (α , β or γ as applicable) and initial values (for the smoothed estimate, trend or seasonality index). Sometimes functions provide these initial values based on certain assumptions. While these assumptions are reasonable, they can be restrictive. These assumptions also determine (to some extent) the output of the functions. It can be confusing for students when the answers they have in textbooks are different from the one in the computer. The functions developed here offer users the choice to provide initial values. They can choose to provide initial values for level and trend (where applicable). Besides, when seasonality is required, users are given different choices on how they provide seasonal indices. These choices permit users to conduct analyses, experimentations and simulations, using different combinations of initial values and the smoothing constants.

3.3 Error Trapping

Smoothing constants take values from 0 to 1 only. The functions developed inform users of the error if values beyond this range are chosen. Similarly, if negative or zero values are entered as the seasonal index then an error occurs. In such cases the outcome will be an appropriate error message. Other kinds of errors are notified by a standard error message (Value!) of UDF.

4 User Defined Functions

Four functions are developed for forecasting. Similarly, three more functions are developed for error measurements. Each of these functions is explained in detail in the paragraphs below. All the functions discussed here are shown in the workbook forecast2.xlsm.

4.1 Simple Exponential Smoothing

There is a function for exponential smoothing in data analysis add-in. Our function for exponential smoothing is different from that one. The look, feel and flexibility of our exponential smoothing function is the same as those of the other three functions discussed here. It has optional "InitialLevel" and "ForecastPeriod" which make it flexible. Otherwise the outcome of both of these functions should be the same.

The function for simple exponential smoothing is "ExpSmooth(Alpha As Single, Actual As Range, Optional InitialLevel As Variant, Optional ForecastPeriod As Variant)"

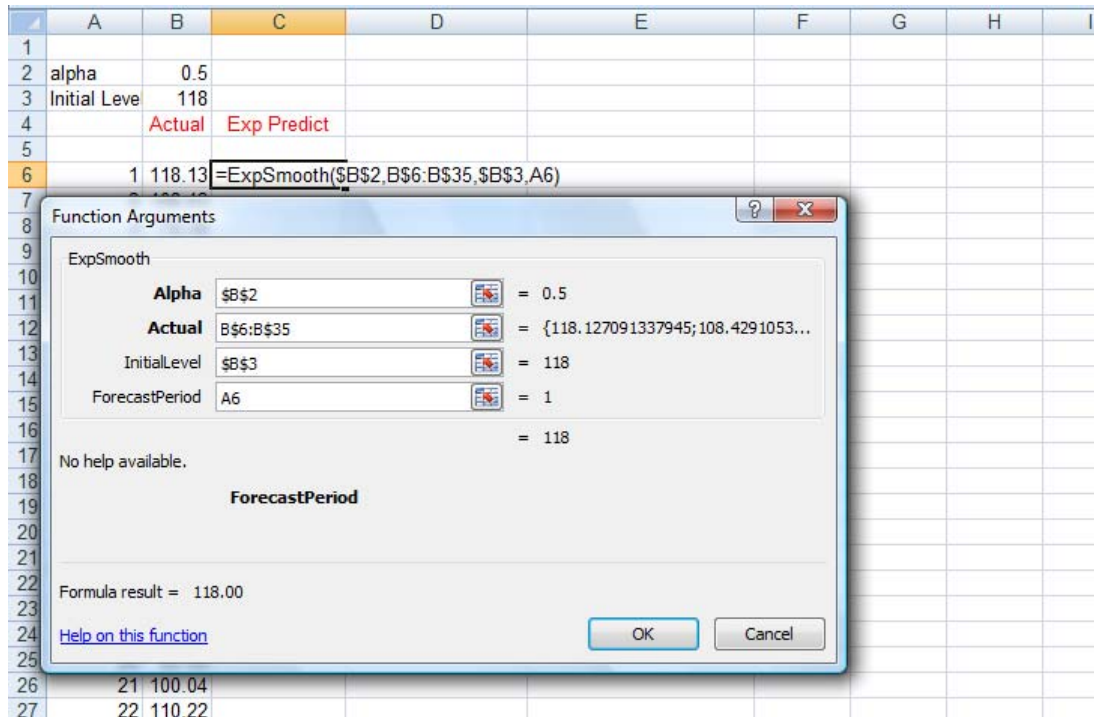


Figure 1: UDF for Simple Exponential Smoothing

For the simple exponential smoothing, users have to provide the α value and a range with actual data. They also have options to provide “InitialLevel” and the “ForecastPeriod”. The old smoothed estimate is the last period’s smoothed estimate. “InitialLevel” replaces the old smoothed estimate when smoothing is done for the very first time. If the user chooses not to provide the “InitialLevel” the actual data of the period one is used in its place. The period one is the period from which actual data is available. Thus, the forecast for “period one” is equal to the “InitialLevel” when it is provided. Otherwise, it is equal to the actual data of period one.

“ForecastPeriod” is the period for which the forecasting is to be done. The value provided for this should be an integer starting from one. If this is provided, forecasting is done for the given period. In case this is not provided, forecast is done for the first period for which the data is not available. If there are actual data for 30 periods, then forecast is done for the 31st period.

To explore the process of the simple exponential smoothing, open the worksheet “EXP”. This worksheet has a thirty period long actual data. The period 1 is the period when actual data is available. After that, choose an appropriate cell on which the forecast value for period one is to appear. In this case that cell is “Range C6”. Then open the “Insert Function” dialogue box (as in Figure 1). This dialogue box can be opened by first clicking the “Formulas” tab on the top of the spreadsheet, and then choosing the “Insert Function” command. Once it appears, choose the “ExpSmooth” function.

As can be seen from the dialogue box, the α value is 0.5 (Range B2 is chosen). The actual data range is from B6 to B35. Choosing “InitialLevel” and “ForecastPeriod” are optional. However, in this case “InitialLevel” is chosen and the value is 118. The

Forecast period is period 1. When “OK” is pressed the dialogue box disappears, and the forecast value is appears in “Range C6”.

	A	B	C	D	E
1					
2	alpha	0.5			
3	Initial Level	118			
4		Actual	Exp Predict	Exp Predict	Exp Predict
5			With Initial Level	Without Initial Level	Without Forecast Period
6	1	118.13	118.00	118.13	110.67
7	2	108.43	118.06	118.13	
8	3	78.58	113.25	113.28	
9	4	122.84	95.92	95.93	
10	5	104.79	109.38	109.39	
11	6	98.41	107.08	107.09	
12	7	101.95	102.75	102.75	
13	8	78.20	102.35	102.35	
14	9	84.70	90.27	90.27	
15	10	116.09	87.49	87.49	
16	11	111.06	101.79	101.79	
17	12	101.19	106.43	106.43	
18	13	88.60	103.81	103.81	
19	14	121.31	96.20	96.20	
20	15	97.39	108.76	108.76	
21	16	123.62	103.07	103.07	
22	17	94.08	113.35	113.35	
23	18	99.84	103.71	103.71	
24	19	80.81	101.77	101.77	
25	20	83.55	91.29	91.29	
26	21	100.04	87.42	87.42	

Figure 2: Simple Exponential Smoothing Complete

The forecast for this period (period one) should be equal to the “InitialLevel” provided. This is equal to 118. The forecast for other periods can be obtained by dragging the edge of cell all the way down to the desired period. (Note how cell addresses are made absolute using the \$ sign.) When the chosen cell is “Range B36” then the corresponding period is 31. The column under the heading “Exp Predict with Initial Level” is completed in this way.

The next column is completed by following a similar process. However, “InitialLevel” is not chosen here. It assumes the first ever actual data to be “InitialLevel”. In another column there is only one value. This is obtained by choosing only the α value, and the range for actual data. The value is the forecast for the first period for which actual data is not available. The complete output of this process is shown in Figure 2.

4.2 Exponential Smoothing with Trend (Holt’s Fit)

The function for Holt’s fit is “HoltFit(Alpha As Single, Beta As Single, Actual As Range, Optional InitialLevel As Variant, Optional InitialTrend As Variant, Optional ForecastPeriod As Variant)”

For the Holt’s fit, users have to provide the α and the β values along with a range with actual data. They also have options to provide “InitialLevel”, “InitialTrend” and the “ForecastPeriod”.

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	A	B	C	D	E	F
1	alpha	0.1				
2	beta	0.2				
3						
4		Actual Demand	Smoothed Forecast, Ft	Smoothed Trend, Tt	Holt FIT	Holt FIT (without initialization)
5	Month	100.1678	100	5	=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A6)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A6)
6	1	105.5326			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A7)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A7)
7	2	106.4641			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A8)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A8)
8	3	106.3257			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A9)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A9)
9	4	103.2784			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A10)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A10)
10	5	105.9517			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A11)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A11)
11	6	105.0688			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A12)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A12)
12	7	112.6189			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A13)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A13)
13	8	103.0878			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A14)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A14)
14	9					
15	10	112.3762			=HoltFit(\$B\$1,\$B\$2,B\$6:B\$35,C\$6,D\$6,A15)	=HoltFit(B\$1,B\$2,B\$6:B\$35,A15)

Figure 3: UDF Formula for Holt's Fit

Here besides Old smoothed estimate the old trend estimate is also required. The old trend estimate is the last period's trend estimate. When smoothing is done for the very first time, "InitialLevel" and "InitialTrend" replace the old smoothed estimate and the old smoothed trend. If the user chooses not to provide these values, the actual data of the period one is used as the default value of "InitialLevel"; and, "InitialTrend" is set to zero. The period one is the period from which actual data is available. For period one, the forecast value is equal to the sum of "InitialLevel" and "InitialTrend" if both are provided. If not, this value is equal to the actual value of period one. The explanation of the "ForecastPeriod" is similar to what we described for the simple exponential smoothing.

Figure 3 shows the worksheet with relevant formulas for Holt's Fit. The actual data for thirty periods appears in this worksheet. In this case the α value is 0.1 and the β is 0.2. The detail of inserting function is the same as above. Column E shows the Holt's Fit when all of the optional information are provided. However, Column F shows the same when initial values ("InitialLevel" and "InitialTrend") are not provided. And, Range "G6" shows the outcome when even the forecast period is not supplied. So, the forecast here is for the period 31. Figure 4 shows the output of this process.

4.3 Exponential Smoothing with Seasonality (Winter's Method)

The function for Winter's fit is "Winter(Alpha As Single, Gamma As Single, Actual As Range, Season As Range, Optional InitialLevel As Variant, Optional ForecastPeriod As Variant)"

For the Winter's fit, users have to provide the α and the γ values along with a range with actual data. In addition, they also have to provide seasonality indices. There are two ways this can be provided. First, they can enter one value equal to the number of seasons. For example, if there are six seasons they can enter "6". Another way is to enter all the seasonal indices. Again, if there are six seasons then there are six indices. None of the indices can be negative or zero. If negative or zero values are entered, an error message appears as the outcome. Also, the total of such indices should be equal to the number of seasons (i.e. six in this case). If the total is different, then the function automatically normalizes each of the indices making the total as required.

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Figure 4: Holt’s Fit Complete

They also have options to provide “InitialLevel” and the “ForecastPeriod”. These terms have the same meanings as discussed in the cases of exponential smoothing and Holt’s fit.

Figure 5: UDF Formula for Winter’s Fit

Figure 5 shows the worksheet with relevant formulas for Winter’s fit. There is an actual data for thirty periods in this worksheet as well. In this case the α value is 0.5 and the γ is 0.5. There are six seasons in this data. Column E shows the forecast when “InitialLevel”, number of seasons and “ForecastPeriod” are provided. However, Column F shows the same when “InitialLevel” is not provided, but the indices of the seasons and “ForecastPeriod” are provided. In this case also the “period one” is the very first period from which actual data is available. The outputs for first six periods (because there are six seasons in this case) are directly dependent on how forecasting is initialized.

Finally, in the case of Range "G6" no information that is optional (including the forecast period) is supplied. So, the forecast is for the period 31. Figure 6 shows the output of this process.

4.4 Exponential Smoothing with Trend and Seasonality (HoltWinter's Fit)

The function for HoltWinter's fit is "HoltWinter(Alpha As Single, Beta As Single, Gamma As Single, Actual As Range, Season As Range, Optional InitialLevel As Variant, Optional InitialTrend As Variant, Optional ForecastPeriod As Variant)"

For HoltWinter's fit, users have to provide α , β and γ values along with a range with actual data. The ways season can be provided is the same as in the case of Winter's fit discussed above. And options on providing or not providing "InitialLevel", "InitialTrend" and "ForecastPeriod" are also as discussed above.

Figure 7 shows the worksheet with relevant formulas for HoltWinter's Fit. There is a data for thirty periods in this worksheet as well. In this case, α , β and γ each have a value of 0.5. There are six seasons in this data. Column F shows the forecast when initial level, number of seasons and forecast periods are provided.

Time	Sales	Level	Seasonal Factor	Forecast	Forecast	Forecast
Pe Data	Level	Factor	nitial Level, with # of sea	Level, with seasons sea	hout Forecast Peri	
1	106.67		1.1	106.67		110.01
2	133.39		1.3	133.40		
3	123.45		1.2	123.46		
4	100.28		0.99	100.28		
5	72.87		0.75	72.88		
6	65.17	100.31	0.66	65.17		
7	104.23			106.67		
8	132.17			131.87		
9	115.72			122.18		
10	99.17			96.62		
11	73.30			71.14		
12	64.98			64.59		
13	105.40			105.42		
14	133.71			132.66		
15	118.72			121.52		
16	95.78			99.56		
17	73.14			71.05		
18	62.44			64.09		
19	114.32			102.79		
20	127.02			136.90		
21	122.08			119.46		
22	97.29			99.71		
23	72.17			72.88		
24	68.78			63.59		
25	113.26			111.11		
26	134.76			135.23		
27	118.83			125.21		
28	99.19			99.58		
29	71.48			73.81		
30	67.89			65.10		
31				110.01		
32				131.87		
33				120.82		
34				99.81		
						98.57

Figure 6: Winter's Fit Complete

However, Column G shows the same when "InitialLevel" is not provided, but the indices of all the seasons and forecast periods are provided. And in the case of Range "H6" no information that is optional, including the forecast period is supplied. So, the forecast is for the period 31. Figure 8 shows the output of this process.

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	A	B	C	D	E	F	G	H
1	alpha	0.5						
2	beta	0.5						
3	gamma	0.5						
4						# of seasons	6	
5	Time	Actual	Base	Seasonal		Forecast	Forecast	Forecast
6	Period	Sales	Level	Trend	Factor	(with Initial Level, with # of seasons)	without Initial Level, with seasons seasonal indices	Without Forecast Period
7	1	106.67			1.1	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A7)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A7)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A7)
8	2	131.15			1.3	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A8)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A8)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A8)
9	3	127.23			1.2	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A9)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A9)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A9)
10	4	103.22			0.99	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A10)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A10)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A10)
11	5	73.056			0.75	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A11)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A11)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A11)
12	6	63.736	100.84	0	0.66	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A12)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A12)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A12)
13	7	99.428				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A13)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A13)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A13)
14	8	128.17				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A14)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A14)	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,\$G\$4,...,\$A14)

Figure 7: UDF Formula for HoltWinter's Fit

	A	B	C	D	E	F	G	H
1	alpha	0.5						
2	beta	0.5						
3	gamma	0.5						
4						# of seasons	6	
5	Time	Actual	Base	Seasonal		Forecast	Forecast	Forecast
6	Period	Sales	Level	Trend	Factor	(with Initial Level, with # of seasons)	without Initial Level, with seasons seasonal indices	Without Forecast Period
7	1	106.67			1.1	110.9	106.7	135.5
8	2	131.15			1.3	131.1	131.2	
9	3	127.24			1.2	121.0	127.2	
10	4	103.23			0.99	99.8	103.2	
11	5	73.06			0.75	75.6	73.1	
12	6	63.74	100.85	0	0.66	66.6	63.7	
13	7	99.43				110.9	106.7	
14	8	128.18				120.9	124.5	
15	9	114.71				113.5	121.3	
16	10	101.82				93.2	93.4	
17	11	78.15				74.8	68.9	
18	12	71.55				68.8	66.0	
19	13	117.52				117.4	118.4	
20	14	152.07				149.3	155.2	
21	15	140.58				142.2	151.3	
22	16	118.11				122.5	124.9	
23	17	92.38				92.1	87.2	
24	18	80.91				82.8	79.0	
25	19	149.83				133.5	131.7	
26	20	166.95				183.0	186.5	
27	21	157.81				161.7	170.0	
28	22	128.50				135.4	139.6	
29	23	97.95				100.0	97.3	
30	24	90.80				86.1	82.7	
31	25	148.97				148.4	145.0	
32	26	177.25				176.6	177.4	
33	27	158.57				164.8	170.9	
34	28	130.57				134.4	138.9	
35	29	93.81				100.5	99.8	
36	30	87.44				84.4	82.0	
37	31					139.0	135.5	
38	32					161.1	156.9	
39	33					144.6	143.4	
40	34					118.5	119.3	
41	35					88.1	88.3	
42	36					79.2	78.4	
43								

Figure 8: HoltWinter's Fit Complete

	A	B	C	D	E	F	G	H
1	alpha	0.5						
2	beta	0.5						
3	gamma	0.5						
4						# of seasons		
5	Time	Actual	Base	Seasonal		Forecast		
6	Period	Sales	Level	Trend	Factor	(with Initial Level, with # of seasons)		
7	1	106.671880723			1.1	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A7)		
8	2	131.153184252			1.3	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A8)		
9	3	127.236493308			1.2	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A9)		
10	4	103.225164520			0.99	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A10)		
11	5	73.0560768775			0.75	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A11)		
12	6	63.7369256000	100.8	0	0.66	=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A12)	MSE	=mse(B7:B35,F7:F35)
13	7	99.4288095757				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A13)	MAD	=mad(B7:B35,F7:F35)
14	8	128.179878188				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A14)	MAPE	=MAPE(B7:B35,F7:F35)
15	9	114.708075036				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A15)		
16	10	101.819148568				=HoltWinter(\$B\$1,\$B\$2,\$B\$3,\$B\$7:\$B\$36,E\$7:E\$12,\$C\$12,\$D\$12,\$A16)		

Figure 9: UDF Formulas for Error Calculations

4.5 Error Formulas

As discussed above, error should be measured for each forecast. The function for MSE is "MSE(Actual As Range, Forecast As Range)". Similarly, the function for MAD is "MAD(Actual As Range, Forecast As Range)". And, the function for MAPE is "MAPE(Actual As Range, Forecast As Range)".

Figure 9 is the printout of the worksheet "Errors." It shows UDF formulas for error calculations. In Column F the formulas to forecast with Holt-Winter's Fit are shown. In the Ranges G11 to G13 there are three functions for MSE, MAD and MAPE respectively. It is to be noted that, while selecting ranges for error formulas, the first periods are ignored. The forecasts for the first period are the outcomes of initializations. Figure 10 shows the completed worksheet.

Holt-Winter's Fit is used just as an example. Any other forecast method could have been used. As one more example, error calculations for simple exponential smoothing is shown in worksheet "Errors1".

	A	B	C	D	E	F	G	H
1	alpha	0.5						
2	beta	0.5						
3	gamma	0.5						
4								
5	Time	Actual	Base		Seasonal	Forecast		
6	Period	Sales	Level	Trend	Factor	(with Initial Level, with # of seasons)		
7	1	106.67			1.1		110.9	
8	2	131.15			1.3		131.1	
9	3	127.24			1.2		121.0	
10	4	103.23			0.99		99.8	
11	5	73.06			0.75		75.6	MSE 38.22
12	6	63.74	100.85	0	0.66		66.6	MAD 4.59
13	7	99.43					110.9	MAPE 3.96
14	8	128.18					120.9	
15	9	114.71					113.5	
16	10	101.82					93.2	
17	11	78.15					74.8	
18	12	71.55					68.8	
19	13	117.52					117.4	
20	14	152.07					149.3	
21	15	140.58					142.2	
22	16	118.11					122.5	
23	17	92.38					92.1	
24	18	80.91					82.8	
25	19	149.83					133.5	
26	20	166.95					183.0	
27	21	157.81					161.7	
28	22	128.50					135.4	
29	23	97.95					100.0	
30	24	90.80					86.1	
31	25	148.97					148.4	
32	26	177.25					176.6	
33	27	158.57					164.8	
34	28	130.57					134.4	
35	29	93.81					100.5	
36	30	87.44					84.4	

Figure 10: Error Calculations Complete

4.6 Minimizing Error

As mentioned above error is inevitable in any forecasting method. However, forecasters always endeavor to minimize the size of the error. Solver, which is one add-in in excel, can be used to minimize the error.

We have shown the procedure in Figure 11. The figure shows the solver dialogue box. First, H11 is the target cell chosen; it stores the value for MSE. MSE is to be minimized, so "Min" button is selected. The selection in "By Changing Cells" shows that values for α , β and γ can be changed. The constraints are shown in "Subject to

constraints” box. There are two constraints. The first one is the values of α , β and γ cannot be more than one. Again, the second is that their values should be more than or equal to zero. Once these steps are completed, the problem can be solved by pressing “Solve” button. Figure 12 shows the outcome. Note that the α , β and γ values have changed and MSE has gone down to 34.20 from 38.22.

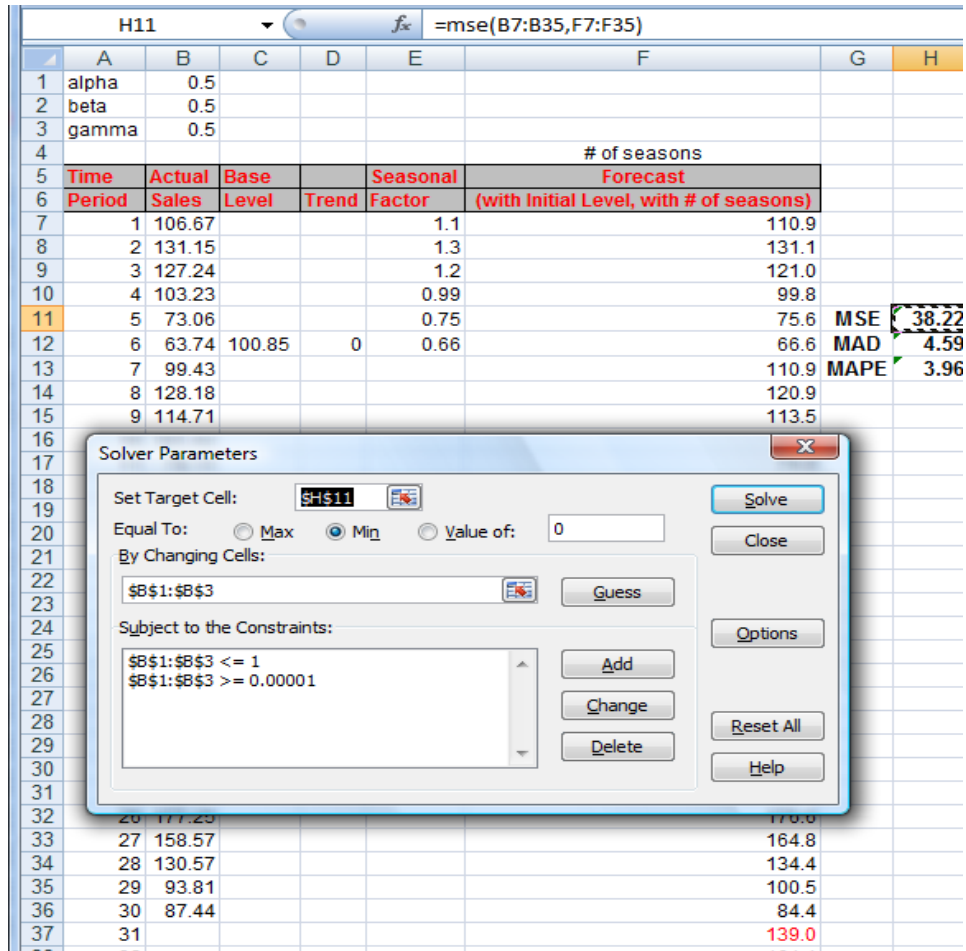


Figure 11: Error Minimization Using Solver

Interested readers can also try to minimize error in simple exponential smoothing, using worksheet “Errors1”. Here only α value has to be changed. Similar method can be used to minimize errors in other forecasts as well.

However, it should be noted that this is a non-linear programming. The output of non-linear programming is the local optimization. That means the minimum value depends on the starting values of α , β and γ . So, before coming to firm conclusion forecasters should try with different values for these constants and see how minimum value for error changes. Readers interested in detail discussion on non-linear programming and error minimization are directed to relevant textbooks [for example 7].

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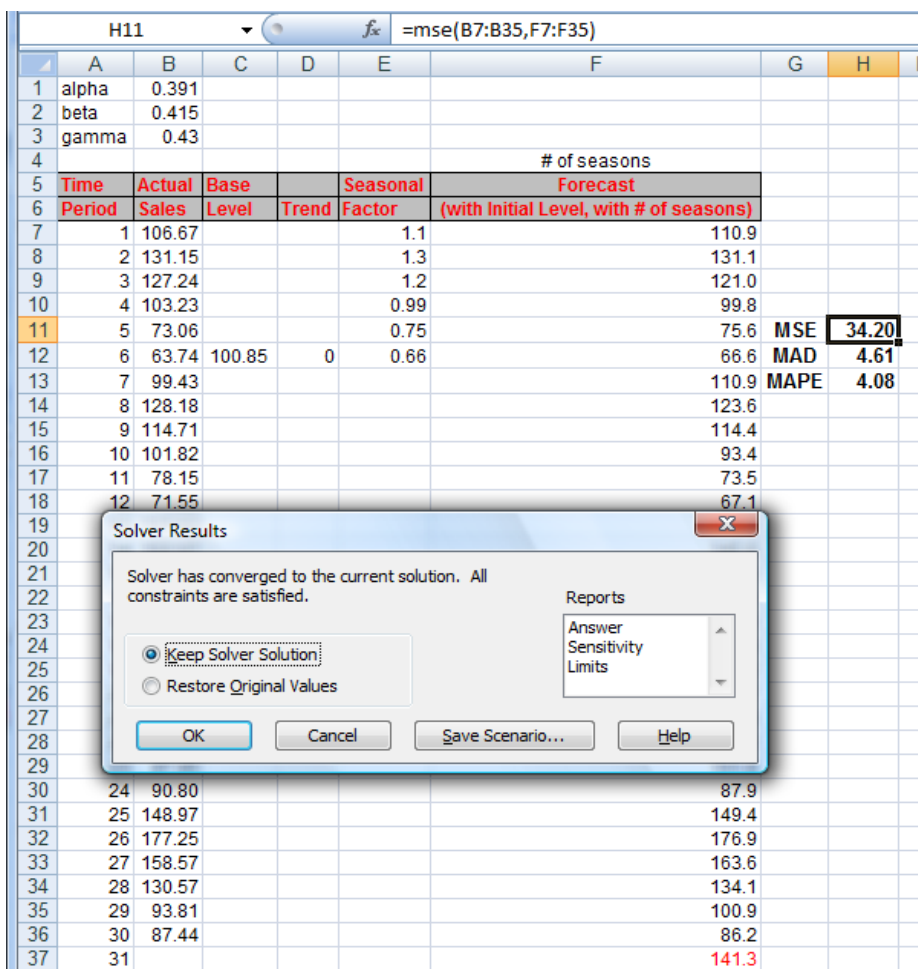


Figure 12: Solver Output for Error Minimization

5 Discussions

All of the outputs discussed here are in the workbook Forecast2.xlsm. The data for these problems are artificially created. Before using the functions to analyze these data, they were tested to solve problems in textbooks [such as 7, 9].

In using these functions, the convention when forecast period is 1 should be noted. More importantly, functions developed here are just for illustration and academic discussions. For any other use, further testing and modification of functions may be necessary. Users should also see whether the particular forecasting model (used here) is appropriate for their purpose.

6 Conclusion

This article presents (and describes in detail) seven user defined functions (UDF) we developed. Out of these, four functions are for exponential smoothing and three are for error measurements. These functions were developed using visual basic for application (VBA) in Excel. Users can use these functions and get their desired output directly. Using these functions removes the need for intermediate steps and make exponential smoothing models (such as Winter’s Model and HoltWinter’s

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model), as well as error measurements, easier to implement. Besides ease of implementation, these functions are also flexible. Thus, these simple functions enhance Excel's usefulness in forecasting.

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