

The 2nd Order Polynomial Next Bar Forecast System

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In a previous paper we examined a trading system, called “The Next Bar Forecast System”. That system fit a straight line, through “N” past prices, and then used the straight line coefficients to forecast the next price.. The Next Bar Forecast curve was constructed by calculating the forecasted next price (p_f) at each bar and plotting it under the price chart. In general what the system did was to follow the plotted curve of p_f . When the curve increased by a percentage amount $pctup$ from the previous prior low of the curve the system goes long. When the curve fell by the percentage amount $pctdn$ from the previous prior high of the curve the system went short..

The problem with the least squares straight line p_f curve is that many times it doesn't turn fast enough to follow fast moving price changes. Here we will use a use a 2nd order polynomial, which we will call 2P, to fit N past prices and generate a curve based on the next bar forecast of the 2nd order polynomial. The resultant curve, because if it's a higher polynomial order will change direction faster than the straight line curve when the price series changes direction. The mathematics for finding the least squares 2nd order polynomial coefficients is the same, though more complicated, as finding the coefficients of a straight line fit. The equation for the 2P line is $p_{est}(t) = b_0 + b_1*t + b_2*t^2$. Where $p_{est}(t)$ is the price estimate of the least squares fit at time t .

The Least Squares 2nd Order Polynomial Line.

Let us imagine a set of closing prices on a graph with time as the horizontal axis and price as the vertical axis. Let us further suppose that we have only twenty closing price dots at twenty time intervals. How can we draw a 2nd order polynomial through those twenty prices such that the sum of all the squared differences between the prices at each time interval and the parabolic line that is being fit to the data is minimized? This is called the “Least Squares Fit” of the data. This mathematical technique is available in most of today's technical analysis software.

The formula for the 2nd order polynomial is:

$$p(t)_{EST} = b_0 + b_1*t + b_2*t^2$$

Where $p(t)_{EST}$ is the estimated price found from the least squares fit at time t .

If N is the number of bars of price data, then b_0 , b_1 and b_2 for the least squares best fit line are given by the equations:

$$b_1 = b_{11}*\Sigma p(t) + b_{12}*\Sigma t*p(t) + b_{13}*\Sigma t^2*p(t)$$

$$b_2 = b_{21}*\Sigma p(t) + b_{22}*\Sigma t*p(t) + b_{23}*\Sigma t^2*p(t)$$

$$b_0 = \Sigma p(t)/N - b_1*(N+1)/2 - b_2*(N+1)(2N+1)/6$$

Where:

$$b_{11} = -18(N+1)(N+2)(2N+1)/den$$

$$b_{12} = 12(2N+1)(8N+11)/den$$

$$b_{13} = -180(N+1)/den$$

$$b_{21} = 30(N+1)(N+2)/den$$

$$b_{22} = -180(N+1)/den$$

$$b_{23} = 180/den$$

$$den = N(N+1)(N+2)(N-1)(N-2)$$

Where all summations are from $t=1$ to N and where $p(N)$ is today's price, $p(N-1)$ is yesterday's price and $p(1)$ is the price N days ago.

The coefficient $2*b_2$ is the parabolic acceleration and was used in a previous article entitled "The Acceleration System" .

While these equations are correct, the implementation of them may cause a few computational problems. The first problem is slow speed. The computation of the polynomial coefficients at each bar using the equations above is very slow. The second problem is floating point overflow. The summations in the polynomial coefficients can become very large causing floating point overflow and computational errors. To solve these problems I developed a fast efficient algorithm, similar to the Lagrange coefficients method discussed in the Nth Order Polynomial papers, that solves the above noted numerical floating point overflow problems and is super fast.

The forecast of the next bar's close, p_f , using the best fit parameters b_0 , b_1 and b_2 calculated above is given by the equation:

$$P_f = b_0 + b_1*(N+1) + b_2*(N+1)^2$$

The 2P Next Bar Forecast System Defined

The least squares 2nd order polynomial forecast is constructed by calculating p_f each day and plotting it under the price chart. If we define N as the number of days in the calculation, then p_f can be calculated by the above formulas. In general what we will be doing is following the plotted curve of p_f . When the curve increases by a percentage amount *pctup* from the previous prior low of the curve we will go long. When the curve falls by the percentage amount *pctdn* from the previous prior high of the curve we will go short.

Buy Rule:

IF p_f has moved up by more than the percentage amount of *pctup* from the lowest low recorded in p_f while short then **buy at the market**.

Sell Rule:

IF p_f has moved down by more than the percentage amount *pctdn* from the highest high recorded in p_f while long then **sell at the market**.

Intraday Bars Exit Rule:

Close the position 15 minutes before the E-Mini close (no trades will be carried overnight).

Intraday Bars First Trade of Day Entry Rule:

Ignore all trade signals before 10:00 EST (30 minutes after the open). Buy and Sell rules above we have included a first trade of the day entry rule. We've included this rule because often there are gaps in the open creating immediate system buys and sells. Many times these gaps are closed creating a losing whipsaw trade. In order to avoid the opening gap whipsaw trade problem we've delayed the first trade of the day for 30 minutes until after 10:00 EST

Testing The Least Squares Parabolic System Using Walk Forward Optimization

There are three system parameters to determine:

1. N , is the lookback period to calculate the p_f ..
2. $pctup$, The percent amount the curve has to increase from a previous prior low of the curve to issue a buy signal
3. $pctdn$, The percent amount the curve has to decrease from a previous prior high of the curve to issue a sell signal.

We will use 1 minute bar prices of the E-Mini futures contract traded on the CME and known by the symbol ES to test the 2P Next Bar Forecast System..

To test this system we will use a statistical technique call "Walk Forward Out-Of-Sample Testing". To use the walk forward testing method, we will break the test data up into twenty 30 calendar day test sections and run a TradeStation optimization on each of those test sections. We will then use an Excel filter, described later, on the TradeStation optimization output of each of those twenty test sections to find the system input parameters N , $pctup$, and $pctdn$. We will then use the input parameters found in the test data by the Excel filter on the out-of-sample data on the week directly following the test section data

For each test section we will run a TradeStation optimization on:

1. N from 10 to 70 in steps of 5.
2. $pctup$ from 0.3 to 1.1 steps of 0.05
3. $pctdn$ from 0.3 to 1.1 in steps of 0.05

This will produce 3757 different cases or combinations of the input parameters. On each of the 20 runs of test data we will export the TradeStation optimization run by saving it to an Excel file.

Why use the walk forward technique? Why not just perform the TradeStation optimization on the whole price series and choose the input parameters that give the best total net profits or profit factor? Surely the price noise cancels itself out with such a large number of test prices. Unfortunately, nothing could be farther from the truth! Optimization is a misnomer and should really be called combinatorial search. That is, we have the TradeStation software calculate certain selected performance parameters, like total net profits, for every combination of input parameters that we tell the optimization module to run. Whenever you run a combinatorial search over many different combinations of input parameters on noisy data on a fixed number of prices, **no matter how many**, the best performance parameters found are guaranteed be due to "curve fitting" the noise and signal. What do we mean by "curve fitting"? Price series that we trade consists of random spurious price movements which we call noise and repeatable price patterns

(if there). When we run, say, 5000 different input parameter combinations, the best performance parameters will be from those system input variables that are able to produce profits from the price pattern **and** the random spurious movements. While the price patterns, *if there*, will repeat, the same spurious price movements will not. If the spurious movements that were captured by a certain set of input parameters were a large part of the total net profits, then choosing these input parameters will produce losses when traded on future data. These losses occur because the spurious movements will not be repeated in the same way. This is why system optimization or combinatorial searches with no out-of-sample testing cause losses when traded in real time from something that looked great in the test section. Unfortunately it is human nature to extrapolate past performance to project future trading results and so results from curve fitting give the **illusion**, a siren call so to speak, of future trading profits.

In order to gain confidence that our system input parameter selection procedure on test data will produce profits “on average” in the future we must perform the walk forward out-of-sample analysis many times. Why not just do the analysis once? Well just as in poker, where there is considerable vagaries in hand to hand luck, walk forward out-of-sample analysis give considerable vagaries in week to week out-of-sample profit “luck”. That is, by pure chance we may have chosen some input parameter that did well in the test section data **and** the out-of-sample section data. In order to minimize this type of “luck”, statistically, we must repeat the walk forward out-of-sample (oos) analysis over many test/oos sections and take an average of our weekly results over all out-of-sample sections. This average gives us an expected weekly return and a standard deviation of weekly returns which allows us to statistically estimate the expected equity and its range for N weeks in the future. More on this later.

To find the system input parameters we will use an Excel autofilter on each of the twenty test section optimization runs. What is an Excel autofilter? Each TradeStation optimization output file has 3757 rows of the different combinations of the input values and a number of performance statistic columns. For instance, one column would be Total Net Profits, another column would be Profit Factor, Percent Profitable and so on. These columns are user selectable in the TradeStation optimization module. When we export the optimization output into an excel spreadsheet we have the columns we selected and the rows which would be the 3757 cases for our example. Excel has a feature called the autofilter. The autofilter allows us to tell Excel to only show those rows that satisfy some criteria on a column or columns. For instance if one of my columns of data was the Profit Factor(PF) for each case, I could tell Excel that I only wanted to show those cases that had PF's of greater than or equal to 1.0. Excel would then hide all other rows and only display those rows that satisfied my PF criteria.

Using Excel's auto filter we will apply the following screen or filter to each test section run.

Filter: PF>=1 and LR<=5 and #Trds<=40.

Where:

- PF = Profit Factor in Test optimization section
- LR=Maximum consecutive losses in a row in test optimization section. Since in real time it is tough to sustain more than five losses in a row and still keep trading, we will eliminate all those cases that have more than five losses in a row
- #Trds = The number of trades in the test run. We want our system to trade almost every day but because of the costs of slippage and commissions not too many times a day. In addition

we want to try and catch the major trend of the day There are 20 to 23 trading days a month, so we only want to look at input parameters that do not generate more than 40 trades in the one month test sample.

This filter in excel will leave anywhere from 10 to 200 cases that satisfy the above filter conditions. Out of the cases that are left we will choose the case that has **smallest drawdown**. This selection procedure on the test optimization run will leave only one choice for the system input values of N , $pctup$, and $pctdn$. We will then use these input values on the next week of 1minute bar E-Mini prices following the test section.

Results

Figure 1 presents a table of the twenty test and out-of-sample windows and the selected optimum parameters and out-of-sample results using the Excel filter described above.

Figure 2 presents a specialized percentage trade by trade summary of the two one week out-of-sample data segments ending on 7/12/04 through 7/23/04. where the out-of-sample input values for those out-of-sample weeks were the same and were $N=50$, $pctup=0.65$ and $pctdn=0.45$.

Figure 3 presents the out-of-sample 1 minute bar chart of ES from 7/22/04 to 7/23/04. with the 2P Indicator and all the buy and sell signals for those dates from the trade by trade summary of Figure 2 indicated on the charts.

Discussion of System Performance

At the bottom of Figure 1 are some statistics that are of interest. The first statistic $ave=\$308$ is the average weekly net profit for the twenty out-of-sample weeks. $Std=\$627$ is the standard deviation of the weekly return. Given a process that generates the above average and standard deviation, it would be interesting to know statistically the probabilistic outcome from trading this system for 13 weeks (one quarter). There is a statistical technique called bootstrap Ref [1]. Using the bootstrap technique we would randomly choose 13 of the twenty weekly profits in Figure 1, with replacement and take the sum of those 13 randomly chosen out-of-sample profits. "With replacement" means we don't eliminate the randomly chosen weekly profit from being chosen again. Let us suppose that we repeat this random choosing of 13 weeks and summing the results 200 times. We would then have 200 different 13 week net profit summations. If we take the average and standard deviation of those 200 different 13 week net profit summations we would have an estimate of what to expect from this system by trading it for 13 weeks.

For this system the 200 bootstrap average of 13 week net profits is \$4080 and the standard deviation is \$2144. This means that at two standard deviations we can expect our 13 week return from this system to be between -\$208 and \$8368 95% of the time. This is quite a range and indicates that 13 weeks of trading is not enough time to judge the results of trading this system. Assuming that the bootstrap averages are from a normal distribution an interesting number is called the 99% breakeven time. This is how many weeks do we need to trade this system so that we have a 99% probability that the equity after those number of weeks will be greater than zero. The answer is 19 weeks. That is, there is less than a 1% chance that our equity will be negative after 19 weeks of trading . Please note that slippage and commissions were not taken into account so the numbers obtained above are higher that could be attained from actual trading..

To see the effect of walk forward analysis take a look at Figure 1. Notice how the input parameters N, pctup and pctdn takes sudden jumps from high to low and back . This is the walk forward process quickly adapting to changing volatility conditions in the test sample.

In observing the chart for the two days of 7/22 and 7/23 we can see that the system did very well in catching the major intraday trend of the E-Mini on those days. When the morning trend changed in midday on 7/22 the 2P next bar forecast system changed direction quickly allowing for the capture of the profits from the trend change to the close of trading. Overall the 2P Next Bar Forecast system did a good job in minimizing the losses due to the inevitable whipsaws that will occur in any trading system and maximizing the profits from the major intraday trend moves of the E-Mini.

References

1. Efron, B., Tibshirani, R.J., (1993), “An Introduction to the Bootstrap”, New York, Chapman & Hall/CRC.
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Info on Dennis Meyers

Dennis Meyers (info@MeyersAnalytics.com.) has a doctorate in applied mathematics in engineering. He is a private trader, and president of Meyers Analytics (www.MeyersAnalytics.com). His firm specializes in Financial Engineering consulting for financial institutions and developing publicly available algorithmic trading software.

Figure 1 Walk Forward Out-Of-Sample Performance Summary for The E-Mini 2P Next Bar Forecast System

ES-1 min bars 02/4/2004 - 7/16/2004 using the below filter on each test segment. The input values N, pctup, and pctdn are the values found from applying the filter to the test sample optimization run.

Filter: PF>=1; LR<=5; #Trds<=40; Smallest Drawdown.

Week	Test Dates	Out-Of-Sample Dates	osnp	Equity	ollt	odd	ont	N	pup	pdn
1	02/04/04 To 03/05/04	03/08/04 To 03/12/04	\$2,313	\$2,313	(\$150)	(\$250)	7	45	0.85	0.55
2	02/11/04 To 03/12/04	03/15/04 To 03/19/04	\$225	\$2,538	(\$400)	(\$663)	8	45	0.85	0.55
3	02/18/04 To 03/19/04	03/22/04 To 03/26/04	\$100	\$2,638	(\$275)	(\$538)	8	45	0.95	0.55
4	02/25/04 To 03/26/04	03/29/04 To 04/02/04	\$38	\$2,676	(\$213)	(\$413)	6	50	0.90	0.55
5	03/03/04 To 04/02/04	04/05/04 To 04/09/04	\$525	\$3,201	\$0	\$0	3	60	1.10	0.60
6	03/10/04 To 04/09/04	04/12/04 To 04/16/04	\$213	\$3,414	(\$300)	(\$300)	7	55	1.10	0.50
7	03/17/04 To 04/16/04	04/19/04 To 04/23/04	\$925	\$4,339	(\$338)	(\$338)	8	60	1.00	0.60
8	03/24/04 To 04/23/04	04/26/04 To 04/30/04	\$888	\$5,227	(\$350)	(\$538)	8	50	1.05	0.60
9	03/31/04 To 04/30/04	05/03/04 To 05/07/04	(\$13)	\$5,214	(\$250)	(\$775)	8	55	1.05	0.60
10	04/07/04 To 05/07/04	05/10/04 To 05/14/04	(\$725)	\$4,489	(\$338)	(\$900)	13	45	1.00	0.30
11	04/14/04 To 05/14/04	05/17/04 To 05/21/04	\$163	\$4,652	(\$188)	(\$425)	8	45	1.00	0.40
12	04/21/04 To 05/21/04	05/24/04 To 05/28/04	(\$363)	\$4,289	(\$625)	(\$625)	8	45	1.00	0.40
13	04/28/04 To 05/28/04	05/31/04 To 06/04/04	\$88	\$4,377	(\$113)	(\$125)	4	35	1.10	0.30
14	05/05/04 To 06/04/04	06/07/04 To 06/11/04	\$500	\$4,877	(\$350)	(\$350)	5	60	0.35	1.00
15	05/12/04 To 06/11/04	06/14/04 To 06/18/04	\$363	\$5,240	(\$13)	(\$13)	5	15	0.40	1.05
16	05/19/04 To 06/18/04	06/21/04 To 06/25/04	(\$450)	\$4,790	(\$325)	(\$613)	6	15	0.80	1.05
17	05/26/04 To 06/25/04	06/28/04 To 07/02/04	(\$38)	\$4,752	(\$313)	(\$488)	7	45	0.75	0.50
18	06/02/04 To 07/02/04	07/05/04 To 07/09/04	\$500	\$5,252	(\$25)	(\$25)	4	35	0.75	0.30
19	06/09/04 To 07/09/04	07/12/04 To 07/16/04	\$300	\$5,552	(\$188)	(\$300)	10	50	0.65	0.40
20	06/16/04 To 07/16/04	07/19/04 To 07/23/04	\$600	\$6,152	(\$388)	(\$875)	11	50	0.65	0.45
OSNP AVG			\$308							
OSNP STD			627							
200 Boot 13wk Sum AVG			\$4,080							
200 Boot 13wk Sum STD			2,144							
99% Breakeven			19.4wks							

Where

PF = Profit Factor in Test optimization section

LR=Maximum consecutive loses in a row in test optimization section

#Trds = Number of trades in the test section.

osnp = Weekly Out-of-sample net profit

ollt = The largest losing trade in the out-of-sample section.

odd = The close drawdown in the out-of-sample section.

ont = The number of trades in the out-of-sample week.

Equity = running sum of the weekly out-of-sample net profits

FIGURE 2 Specialized Trade By Trade Summary
E-Mini 1min Bars 2P Next Bar Forecast System 7/12/2004 - 7/23/2004

Entry Date	Entry Time		Entry Price	Exit Date	Exit Time	Exit Price	Bars InTrd	Trade \$P&L	Trade Max\$Pft	Trade Time	Trade Max\$DD	Trade Time
07/12/04	901	Sell	1110.50	07/12/04	1326	1112.50	265	(\$100)	\$188	920	(\$150)	1323
07/12/04	1326	Buy	1112.50	07/12/04	1500	1113.75	94	\$63	\$175	1338	(\$38)	1327
07/13/04	901	Buy	1115.50	07/13/04	1500	1115.00	359	(\$25)	\$13	1322	(\$150)	1047
07/14/04	932	Buy	1113.75	07/14/04	1213	1114.00	161	\$13	\$275	1037	\$0	932
07/14/04	1213	Sell	1114.00	07/14/04	1500	1110.50	167	\$175	\$325	1433	(\$50)	1255
07/15/04	901	Sell	1112.00	07/15/04	1200	1113.50	179	(\$75)	\$225	1042	(\$125)	1147
07/15/04	1200	Buy	1113.50	07/15/04	1408	1109.50	128	(\$200)	\$50	1204	(\$213)	1406
07/15/04	1408	Sell	1109.50	07/15/04	1500	1106.00	52	\$175	\$175	1500	(\$50)	1420
07/16/04	907	Sell	1109.00	07/16/04	1500	1101.00	353	\$400	\$438	1455	\$0	907
07/19/04	901	Sell	1103.75	07/19/04	1327	1102.00	266	\$88	\$400	1248	(\$38)	902
07/19/04	1327	Buy	1102.00	07/19/04	1500	1100.00	93	(\$100)	\$163	1348	(\$138)	1451
07/20/04	918	Sell	1098.75	07/20/04	1314	1106.50	236	(\$388)	\$13	920	(\$388)	1313
07/20/04	1314	Buy	1106.50	07/20/04	1356	1104.25	42	(\$113)	\$88	1340	(\$188)	1350
07/20/04	1356	Sell	1104.25	07/20/04	1500	1108.00	64	(\$188)	\$0	1356	(\$188)	1443
07/21/04	901	Buy	1112.75	07/21/04	1019	1111.00	78	(\$88)	\$150	920	(\$88)	1009
07/21/04	1019	Sell	1111.00	07/21/04	1500	1093.25	281	\$888	\$888	1500	(\$50)	1028
07/22/04	901	Sell	1089.50	07/22/04	1121	1090.00	140	(\$25)	\$313	1048	(\$113)	915
07/22/04	1121	Buy	1090.00	07/22/04	1459	1095.50	218	\$275	\$450	1437	(\$88)	1227
07/22/04	1459	Sell	1095.50	07/22/04	1500	1095.25	1	\$13	\$13	1500	(\$13)	1459
07/23/04	901	Sell	1089.25	07/23/04	1500	1084.50	359	\$238	\$338	1406	(\$100)	953

Figure 3 ES 1min 2P Next Bar Forecast System 7/22/04 to 7/23/04

