## Case History: Using Design of Experiments Technology to Improve the HR Trading System


Ronald Schoenberg, Ph.D.

Trading Desk Strategies, LLC

ronschoenberg@optionbots.com

www.optionbots.com


Here at Trading Desk Strategies we've developed a trading system based on options on the S&P 500. The basic unit is a spread we call the HR spread. The spread is opened with a specified credit, usually $40,000, and is neutral with respect to short and long options. Profits are made when the short options are bought back for less than we sold them. The sale of short options generates excess long options which are held for protection against large movements in the market. Both call and put HR spreads are opened creating, at least initially, a risk profile of a short strangle with a wide profit plateau in the middle where all options expire out of the money and we keep the remaining credit. The actual progress of the portfolio over time is somewhat more complicated however because as the market moves up and down short positions are bought back and more spreads opened creating a complex arrangement of short and long call and put options.

A computer program was written using C# with the GAUSS Run-Time Module [1] for statistical and mathematical calculations to manage the trading of the HR spreads. An option chain, a table of calls and puts for all currently available strikes and expires, is downloaded in real time each minute of the trading day and processed for eligible spreads. If any is found that satisfies a rather complex set of requirements, a signal is issued. For paper-trading the signals are maintained in a database with a paper account. For actual trading, the signal would be sent to a trader.

Over ten thousand candidate spreads are scrutinized in every option chain. Market conditions are also measured and analyzed. Whether or not a signal is issued depends on a large set of parameter settings. Initially these settings were determined by what we call "brute force back-testing". Many simulated runs over many expiries were conducted with a variety of settings looking for the best overall outcome.

What emerged from this early testing of the model was that it was going to be difficult to find consistent settings with profitable outcomes in all types of market conditions. The overall outcome tended to be small with settings that worked well in one type of condition but poorly in another condition.

We then decided to apply Design of Experiments (DOE) technology (http://en.wikipedia.org/wiki/Optimal_design) to our trading model. This would have the following beneficial effects: first, we seek to find optimal parameter settings for each market condition, allowing us to see whether any of them can be found to vary by some market measure such as realized volatility. Second, we might find some set of parameters that produce good outcomes over all market conditions.

## Design of Experiments

To start we select "factors", here the parameters we want to investigate. Our earlier back-testing showed the outcomes to be generally insensitive to many of them. We settled on four parameters, two involving spread selection,

- underlyingDistanceWeight
- creditToMaxExposureRatioWeight

And two involving exit management

- shortTargetFactor
- liquidationFactor

Next we set a region of interest by establishing minimums and maximums for each of our factors. They are [.5, 3] for the selection factors, and [.1, 1] for the exit management factors.

Now a design matrix is generated. The design matrix is a set of trials with parameter settings chosen to satisfy a statistical criterion. We choose the I-Optimal criterion. This criterion minimizes the prediction variance over the region of interest and has been shown generally to produce better results than other criteria. We must also choose the type of polynomial we'll be using for the response surface analysis. There's a trade-off between the order of the polynomial and the number of trials. For the initial study we'll choose a cubic model. We expect the response surface to be somewhat complex and the cubic model provides us with more opportunity to explore that surface. It does entail 35 trials but the greater elasticity of the response surface will be worth the effort.

Using the computer program Gosset (http://www.research.att.com/~njas/gosset/) based on methods developed by Hardin and Sloane [1], the following design matrix was generated based on the specifications described above:

| | | | | |
|---|---|---|---|---|
| 1 | 1.000 | 1.000 | 2.751 | 0.500 |
| 2 | 0.260 | 0.345 | 3.000 | 1.041 |
| 3 | 0.100 | 1.000 | 1.265 | 3.000 |
| 4 | 0.211 | 0.620 | 1.163 | 0.546 |
| 5 | 0.320 | 1.000 | 2.010 | 1.069 |
| 6 | 0.716 | 0.348 | 3.000 | 2.635 |
| 7 | 0.671 | 0.662 | 2.520 | 0.500 |
| 8 | 0.100 | 0.591 | 0.500 | 3.000 |
| 9 | 0.383 | 0.907 | 0.692 | 2.278 |
| 10 | 1.000 | 0.357 | 2.406 | 1.306 |
| 11 | 0.100 | 0.100 | 3.000 | 3.000 |
| 12 | 0.100 | 0.226 | 1.099 | 1.844 |

| | | | | |
|---|---|---|---|---|
| 13 | 0.575 | 0.100 | 0.633 | 2.974 |
| 14 | 1.000 | 1.000 | 0.500 | 3.000 |
| 15 | 1.000 | 0.327 | 0.500 | 0.500 |
| 16 | 0.269 | 0.332 | 2.000 | 3.000 |
| 17 | 0.672 | 1.000 | 0.564 | 0.500 |
| 18 | 1.000 | 0.837 | 0.996 | 1.157 |
| 19 | 0.100 | 0.104 | 2.332 | 0.500 |
| 20 | 0.417 | 0.100 | 2.417 | 2.066 |
| 21 | 0.707 | 0.776 | 1.493 | 3.000 |
| 22 | 0.100 | 1.000 | 0.500 | 0.971 |
| 23 | 1.000 | 0.100 | 0.500 | 1.576 |
| 24 | 0.660 | 0.439 | 0.500 | 1.350 |
| 25 | 0.100 | 1.000 | 3.000 | 0.500 |
| 26 | 0.934 | 0.100 | 3.000 | 0.500 |
| 27 | 0.258 | 0.100 | 0.500 | 0.500 |
| 28 | 0.985 | 0.100 | 2.418 | 3.000 |
| 29 | 0.728 | 0.153 | 1.383 | 0.742 |
| 30 | 0.893 | 1.000 | 2.049 | 2.359 |
| 31 | 0.369 | 1.000 | 3.000 | 3.000 |
| 32 | 0.100 | 0.734 | 2.563 | 2.204 |
| 33 | 1.000 | 0.808 | 3.000 | 3.000 |
| 34 | 0.762 | 0.871 | 3.000 | 1.422 |
| 35 | 1.000 | 0.414 | 1.025 | 2.549 |

Each row is a trial with selected set of parameters values. The HR trading system begins trading spreads about 65 days before expiry, and all profit/losses are realized at expiry. Such a run for a selected expiry constitutes an experiment. We will want to conduct experiments across market conditions. Ultimately we want to find settings that will profit across market conditions. This may be achieved by finding either a set of parameters that succeeds for all market conditions, or some way of tying the parameters to market measures such as realized volatility.

## Security Issues

The design matrix generated by the Gossett program is in a -1,+1 scale where -1 is the minimum value and +1 the maximum value of the parameter. In practice the Design of Experiments could be conducted by a third party, such as Trading Desk Strategies, on behalf of a client without knowing anything about the parameter settings or the model. The factors could be given neutral names such as A, B, etc. The client would be sent the design matrix on the -1,+1 scale. The client would transform it to the scale of their parameters, conduct the trials, and then return only the measured outcomes to Trading Desk Strategies. The response surface analysis would be done in the -1,+1 scale and sweet spots and analysis returned to the client in the -1,+1 scale who would then transform to the original scales of the parameters. In other words, the Design of Experiments technology can be applied without a client having to reveal anything at all about their trading system. The original scales and the names of the parameters are revealed here in this article for verisimilitude, but even as much as has been revealed here doesn't really cause us any worry that we've shown too much of our trading system.

## Trial Runs

For our purposes there are three types of market conditions we'll investigate, (A) the bear conditions around the October 2008 meltdown, the (B) bull condition from early March through the end of May 2009, and (C) the calmer conditions of June and July 2009.

The November expiry is the most vulnerable to the October meltdown. The run starts right after the August expiry on August 18th when the S&P 500 was 1278, and ends on November 20th when it was 752.44. The fall in the market was sufficiently unremitting over this time that opportunities for buying back short puts were too infrequent. The same, but opposite problem, occurred for the May expiry where the unprecedented 30% rise in the market over two months also failed to provide enough opportunities for buying back short calls.

All the remaining expiries under study were like June and July where the only issue is the size of the profit. The task of the analysis, then, is to find either that sweet spot that loses small amounts for November and May while allowing for large profits the remaining expiries, or produce the clues we need to be able to vary the parameters according to some market measure.

Each trial run assumed a $3,000,000 account. The following table shows results for six months

| | Jul-09 | Jun-09 | May-09 | Apr-09 | Dec-08 | Nov-08 | Oct-08 | Sep-08 |
|---|---|---|---|---|---|---|---|---|
| 1 | 24200 | 11450 | 11650 | 37075 | 10825 | -2031175 | 15700 | 26600 |
| 2 | 65850 | 38950 | 46375 | 31525 | 13800 | -2455100 | 33175 | 33075 |
| 3 | 398050 | 411250 | -137525 | 108700 | 33950 | -3203200 | -2134170 | 98875 |
| 4 | 148075 | 114825 | -360775 | 78325 | 77450 | -3108550 | 22575 | 57825 |
| 5 | 324650 | 237950 | 212025 | 111200 | 75825 | -3106625 | -2480640 | 76775 |
| 6 | 108125 | 110800 | -203425 | 34825 | -467800 | -3205800 | 13200 | 42125 |
| 7 | 45700 | 21250 | 40850 | 50775 | 50575 | -2325050 | 21050 | 20950 |
| 8 | 254100 | 240750 | -155275 | 68825 | 420775 | -2567250 | 21225 | 52950 |
| 9 | 405950 | 404750 | -68725 | 106125 | 294700 | -2587650 | -2311340 | 76550 |
| 10 | 93050 | 87950 | 126825 | 13650 | 80650 | -3105600 | 9100 | 33275 |
| 11 | 57175 | 75025 | -88775 | 13425 | -520550 | 4925 | 6400 | 17650 |
| 12 | 118725 | 98700 | -135700 | 22625 | -400825 | -3203200 | 9100 | 24825 |
| 13 | 56250 | 100425 | -83850 | 17575 | 74400 | 4925 | 6400 | 16150 |
| 14 | 432350 | 504100 | -131125 | -2336425 | 48875 | -2426700 | 9100 | 87525 |
| 15 | 134700 | 103950 | -260350 | 24575 | -415475 | -2634725 | 9100 | 42125 |
| 16 | 159275 | 132075 | -132500 | 31675 | 162275 | -2335400 | 13200 | 44875 |
| 17 | 377225 | 257300 | -251300 | -2285625 | -337150 | -3205800 | 18500 | 95550 |
| 18 | 399150 | 299600 | -214200 | -2154950 | -280500 | -3074425 | 9100 | 63000 |
| 19 | 9725 | 10700 | 5200 | 4650 | 18125 | 7200 | 4825 | 9000 |
| 20 | 50125 | 49000 | -269975 | 13425 | -312800 | 4925 | 6400 | 17650 |
| 21 | 363875 | 404025 | -113650 | 48350 | 368550 | -2523125 | 18500 | 82325 |
| 22 | 409775 | 393750 | -121450 | 82550 | -375450 | -2780475 | -2105195 | 98875 |
| 23 | 58375 | 44900 | -217650 | 7725 | 77225 | 4925 | 6400 | 16750 |
| 24 | 156500 | 208250 | -60000 | 84450 | -268175 | -2534100 | 16500 | 63375 |
| 25 | 54050 | 26200 | -92400 | 86525 | 148200 | -3072150 | 31950 | 26600 |
| 26 | 6725 | 2750 | 4050 | 6950 | 10875 | 4500 | 4825 | 4175 |
| 27 | 60875 | 48650 | -181450 | 13425 | -295775 | 4925 | 6400 | 17650 |
| 28 | 68400 | 35525 | -226000 | 7475 | 42175 | 4925 | 6400 | 17650 |
| 29 | 56025 | 44450 | 173575 | 13050 | 57200 | -2333850 | 6400 | 15250 |
| 30 | 333500 | 307025 | -207325 | -1587500 | -329850 | -2333125 | 13200 | 72400 |
| 31 | 434500 | 404125 | -182800 | 82550 | -386500 | -2581900 | -2013230 | 117175 |
| 32 | 283775 | 253825 | -213900 | 61650 | -654375 | -2740350 | -2113550 | 83300 |
| 33 | 329750 | 241125 | -236125 | -1026300 | -643950 | -3153200 | 9100 | 63000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 34 | 218725 | 99300 | 120225 | -2241425 | 192400 | -2427775 | 15825 | 63175 |
| 35 | 162075 | 159200 | -247425 | 55550 | 428925 | -2588525 | 9100 | 60175 |

As can be seen, the expiry months widely vary in their profit/loss profiles. The percent of trials to generate a profit by expiry is

| Jul-09 | Jun-09 | May-09 | Apr-09 | Dec-08 | Nov-08 | Oct-08 | Sep-08 |
|---|---|---|---|---|---|---|---|
| 100% | 100% | 26% | 82% | 60% | 22% | 82% | 100% |

78% of the HR model's parameter settings lose money in the Nov-08 expiry and 74% in the May-09 expiry. Each of these situations are the opposite type of market condition, the former including the Meltdown, and the latter the fastest rise in the market for that period of time. It will be a challenge to find parameter settings that reconcile such dramatically variable conditions, not to mention finding even one for Nov-08.

## The Analysis

The trials results are fit to a cubic model. The response surface is searched for the parameter settings that generate the maximum profit, called the "sweet spot". For this search we use the Sqpsolvemt function in the GAUSS Run-Time Library which solves the nonlinear programming problem with general constraints on parameters. The cubic model is nonquadratic and may have multiple maximums. For this reason the parameter space is divided into 2^4 or 16 quadrants and a maximum is sought within each of these quadrants. Finally, any maximum found on an internal boundary is rejected because it is merely pointing to a maximum in the adjoining quadrant.

The sweet spots for the eight months are

| | Profit/Loss | P1 | P2 | P3 | P4 |
|---|---|---|---|---|---|
| Jul-09 | 463829 | 0.417 | 1.000 | 0.500 | 1.437 |
| | | | | | |
| Jun-09 | 547188 | 0.698 | 1.000 | 0.500 | 3.000 |
| | | | | | |
| May-09 | 236745 | 0.880 | 0.285 | 2.191 | 0.789 |
| | 174879 | 0.550 | 0.272 | 2.053 | 0.886 |
| | | | | | |
| Apr-09 | 1181911 | 0.348 | 0.367 | 0.500 | 2.192 |
| | 831618 | 0.376 | 0.339 | 3.000 | 3.000 |
| | | | | | |
| Dec-08 | 827047 | 0.385 | 0.825 | 0.614 | 3.000 |
| | 754326 | 0.460 | 1.000 | 3.000 | 0.500 |
| | | | | | |
| Nov-08 | -1837566 | 0.346 | 0.880 | 2.395 | 3.000 |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Oct-08 | 1016845 | 0.842 | 0.100 | 3.000 | 1.671 |
| | | | | | |
| Sep-08 | 135123 | 0.100 | 1.000 | 3.000 | 3.000 |

We see in this table wide variation in sweet spots by expiry. This indicates a sensitivity of the parameters to market conditions. It does appear unlikely that a single set of parameters will work for all expiries. Our next step will be to introduce some kind of process control in which the parameters will be adjusted in real time in accordance with measures of market conditions such as realized volatility, market volume, moving average trend information, etc. The Kalman Filter is a well-known method for accomplishing this kind of task (http://en.wikipedia.org/wiki/Kalman_filter).

If we were successful in implementing a type of process control for the parameters, we would have a result similar to a run where the individual sweet spots above prevailed for each expiry. To show what that might be like, we executed a run on the complete set of expiries from Feb-08 through Jul-09. For expiries for which we don't have a sweet spot, we used the Jun-09 sweet spot. The following table displays these results:

| | |
|---|---|
| Jul-09 | 426325 |
| Jun-09 | 475925 |
| May-09 | 46375 |
| Apr-09 | 46675 |
| Mar-09 | 250475 |
| Feb-09 | 268975 |
| Jan-09 | 553250 |
| Dec-08 | 578125 |
| Nov-08 | 4925 |
| Oct-08 | 6400 |
| Sep-08 | 108775 |
| Aug-08 | 63775 |
| Jul-08 | 126000 |
| Jun-08 | 117225 |
| May-08 | 148600 |
| Apr-08 | 31900 |
| Mar-08 | 175025 |
| Feb-08 | 71975 |
| Total | 3500725 |

From one to three portfolios are open at any one time for an average total of $7.5 million at risk. The above result is a 31.1% annualized (uncompounded) rate of return. We recommend for this type of investment that not more than 50% of the account be at risk in which case the return would be 15.6%.

## References

[1] Aptech Systems, Inc., http://www.aptech.com.

[2] R. H. Hardin and N. J. A. Sloane, "A New Approach to the Construction of Optimal Designs", *Journal of Statistical Planning and Inference*, vol. 37, 1993, pp. 339-369