# The Evaluation and Optimization of Trading Strategies

Second Edition

ROBERT PARDO

WILEY

John Wiley & Sons, Inc.

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# Table of Contents

# Additional Praise for *The Evaluation and Optimization of Trading Strategies*

"The *decisive* step in system trading is the determination of the reliability and robustness of your system. This greatly expanded and very accessible new edition of Bob's classic presents a thorough yet easy to apply and timetested methodology to accurately make this determination. This makes it possible to form a realistic idea of how your system should perform in the future and increases the likelihood of lasting real-time trading profit."

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"Bob Pardo has re-written his own excellent book, and made it even better. It contains a basic step-by-step guide to building a trading system, along with an introduction to advanced system building concepts and tools. Simply avoiding the problems and errors Bob warns about can help lead to real time success. A must read for anyone interested in a systematic approach to trading."

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.



***Library of Congress Cataloging-in-Publication Data:***

Pardo, Robert, 1951–
p. cm.–(Wiley trading series)
Rev. ed. of: Design, testing, and optimization of trading systems. c1992.
Includes index.

ISBN 978-0-470-12801-5 (cloth)
1. Investments–Data processing. 2. Futures–Data processing. 3. Options (Finance)–Data processing. I. Pardo, Robert, 1951–Design, testing, and optimization of trading systems. II. Title.
HG4515.5.P37 2008
332.645–dc22
2007038106

# Foreword

My relationship with Bob Pardo goes back to 1996 when he approached my firm, DUNN Capital Management, in search of trading capital for his XT99 system. After some extensive system evaluations, we entered into an agreement to help research, develop, and trade Bob's XT99 for Bob, DUNN, and our clients. I am pleased to report that this arrangement has proved beneficial to all parties and that it is still going great guns. When Bob recently asked if I would write the foreword for this second edition I assured him that I would be more than delighted to do so.

Because of my scientific background and training we have always viewed system design and development as a diligent application of statistical analysis of the performance of trading models and of their test results. Accordingly, we were very pleased to find that many of these features were used in developing the XT99 model platform and that it was so amenable to further testing and fine-tuning.

When my colleagues and I had the opportunity to read the first edition of this work, we were particularly interested in Bob's presentation of the virtues and benefits of using the walk-forward method to guide system development.

I am aware that many consider the first edition of this book to be a classic. Generally speaking, it is pretty difficult to improve upon a classic, but in this case it was necessary. As Bob outlines in his preface, to say that our world of computing, trading, and money management has changed since 1991 when the first edition of this book was published, would be a *dramatic* understatement. Given the vast changes that have occurred since the first edition, a new edition of Bob's book addressing these matters is entirely in

line. The good news here is that not only did Bob update the original material; he also reorganized it, explained the material with even greater clarity and insight and added some new insights that he has learned in the intervening years. Did he improve on a classic? You'll have to be the judge of that yourself.

I have always been impressed with Bob's technical toolbox and his innovative ideas. Bob's focus, dedication, and originality as a researcher and trader are very apparent in this second edition. I think that serious system developers will find this second edition a very interesting and profitable read.

Enjoy it.

William A. Dunn, PhD

Chairman

DUNN Capital Management

Stuart, Florida

*May 2007*

# Preface

## THERE AND BACK AGAIN

The first edition of *Design, Testing, and Optimization of Trading Systems* (DTOTS, as I always think of it) was published in 1991. It would be an understatement to say that the world has changed dramatically in the 17 years between the 1991 edition and this one. Some would say the markets have changed also. I disagree.

The markets do what they always do: incorporate all of the changes in communication, technology, wealth, and trading styles into the instantaneous calculation of their fair value.

I have always considered the defining characteristic of markets to be their ability to adapt and alter themselves accordingly to the changing style of market participants.

In this introduction, we review the principal changes that have occurred during this time and their impact on the markets and trading. Many will seem obvious. Please bear with me in this walk down memory lane, however, for the sum total of these changes has altered the nature of trading and our industry in ways that directly reflect upon the current art of the design and evaluation of trading strategies.

“How?” you might ask, and that would be a very good question. Let me start by offering my reflections on that subject because it is highly relevant to the topic at hand.

# The Trading System: From Rock Bottom to Rock Star

The first, and perhaps foremost, difference was that in the early 1990s, the argument that raged was about whether trading systems actually worked. For those who are relatively new to the industry, this might come as a bit of a shock. There is now such a widespread, and somewhat unquestioned, belief in the many virtues of algorithmic trading (AT) that it almost borders on religious belief.

As one who was rather instrumental in the acceptance of the benefits of algorithmic trading, I find *both* of these polar opposite beliefs somewhat troubling. I was trained in and always have been a fierce advocate of the scientific method and the empirical approach. I have always believed in the critical method.

In our business, the trader who does not apply these methods consistently, rigorously, and religiously along with a healthy dose of skepticism is a trader doomed to failure.

I believed then, and even more so now, that algorithmic trading, when performed correctly and based upon exhaustive research, is the most effective method for large-scale trading. Those of you who go on to read this book will find out in detail why I believe this to be so.

In short, the benefits of AT are many. Central, however, are the elimination of highly fallible human judgment, the precise quantification of risk and return and their application in risk and asset allocation, and the ability to trade a relatively unlimited number of markets. Add to this the current technological ability to enter algorithmically calculated trades electronically and without human intervention and we now have the best of all possible worlds: mathematically sound and objective trading signals entered at the speed of light without the (easy) possibility of

human interference. Of course, there will be more on this later.

If one examines the current climate of the professional commodity trading advisory and money management industry, one will find that algorithmic, or systematic, commodity trading advisers (CTAs) outnumber the discretionary trader 3.5 to 1.[1] This would suggest that the majority of CTAs have adopted the algorithmic trading philosophy. Since it is fair to assume that professional money managers are knowledgeable and sophisticated, pervasive AT adoption would also suggest that it is the choice of the expert.

It is somewhat troubling then, that the trading public, including those who aspire to professional trading, with all of their varying degrees of sophistication, have almost assumed an unquestioning, naïve, and somewhat gullible blind faith in trading systems. It is shocking to me that the relative sophistication of the typical consumer of commercial trading strategies is not that much different today from what it was around 1990.

So, we have witnessed a most dramatic shift in philosophy since the publication of DTOTS, from an ignorant and oftentimes hostile disbelief in the efficacy of the trading system to a dogmatic and somewhat mindless faith in the trading system, and worse, nearly any trading system that seems to make a good case for itself.

Why is this important? It demonstrates two major factors. The first is that the overall depth of education of the trading public has not significantly improved in the last 15 years, whereas there are certainly far more books, software, and instruction available today than circa 1990. I would call much, but not all, of this information, however, to be of a lateral sort of knowledge, as in a variety of kind, in contrast

to in-depth, as in a penetrating knowledge of cause and principle.

The second—and this relates to the first—is that solid knowledge of the principles of trading strategy design and evaluation has not become the common knowledge that one would have thought. This is particularly noticeable to me since I wrote the first edition of this book to remedy what I felt was a dramatic deficiency in the trading literature. Also, because before the publication of DTOTS, I, and the employees of my various businesses, spent a lot of time and money educating our clients in these principles. Perhaps I can make more of an impact with this edition.

## COMPUTING

Perhaps the most amazing transformation in the last 15 years has been the exponential expansion of computing and communications capacity. Let us consider the facts. In 1991, the fastest computer chip available was the Intel 80386 at 25 Megahertz. Today the fastest chip is the Intel Core 2 at 3700 Megahertz. This is a 14,800 percent increase. The number of operations of an Intel 80386 at 25 MHz was approximately 8,500,000 per second. The number of operations of an Intel Core 2 at 3, 333 MHz is 57,000,000,000 operations per second. This is an increase of more than 670,000 percent!

The amount of RAM (computer memory) typical of an Intel 80386 was 1,000,000 bytes or 1 *megabyte* (as in 1 million) of RAM. The typical computer today is equipped with 1,000,000,000 bytes or 1 *gigabyte* (as in 1 *billion*) of RAM. This is a 1,000-fold increase. The current trading applications can use this massive amount of RAM to hold data, multiple time markets, and multiple markets in multiple time frames. However, whereas the computers can

now hold massive amounts of data, the dual bottlenecks of the grossly inefficient Windows XP operating system prevalent on most computers, together with effectively obsolete (but, of course, the leading vendors will vehemently deny this) trading strategy development applications makes processing massive amounts of price data, multiple markets, and multiple time frames highly impractical, if not essentially impossible. This matter has only been made worse by the even poorer performance of Windows VISTA. The processing time involved is typically so massive with these commercial applications as to make it highly undesirable, if not practically impossible.

In contrast, Pardo Capital Limited uses in-house proprietary applications for most of the heavy-duty computing that we professional trading firms must do when developing trading platforms.

The typical amount of hard drive storage space on an Intel 80386 was 40 megabytes. The typical amount of hard drive storage space on current computers is 250 gigabytes. This is a 5,000 percent increase. Back in the 1990s, storage space and RAM were at a premium; now they are so cheap and massive that for the purposes of the trading strategist they are as if infinite. With this massive storage capacity, it should now be possible for the strategist to store his research in a comprehensive, searchable, and hence statistically analyzable database. However, what is lacking is the trading software that places the strategist's research in sophisticated databases. Also, save for those who create their own software applications, the ability to analyze such a research database in a sophisticated manner is unavailable.

Why is this important? If processing power has increased by 14,800 percent, RAM by 1,000 percent and storage capacity by 5,000 percent, it would not be terribly unreasonable for the strategist to expect that trading

applications that perform testing and simulations and that update real-time market analysis should have enjoyed a performance boost at least somewhat similar in proportion. However, they have not. They have not even come close. This is highly relevant.

As both a software developer and a trading strategy developer back in the 1990s, I would have been put into a frenzy by the prospects that such increased computer capacity would have offered to the design and optimization of trading systems.

The truth is that, because of the bottlenecks presented by inefficient operating systems, database management tools, and trading applications, the average trader has not been able to harness the possibilities that lurk in his PC. They are now only available to those who have the resources to assemble teams of application designers and developers with the knowledge and sophistication to design and create such complex applications and harness the full capacity of the hardware available and to come.

The evening of the trading strategy playing field that was emerging in the early 1990s has long vanished. Once again, the large trading entities have a massive advantage. And believe me, they use it to the fullest extent possible.

Need we look much further than a $9.54 billion profit for 2006 for Goldman Sachs or the huge assets ($26.3 billion) under management and outstanding returns (annual returns exceeding 20 percent) of D.E. Shaw for proof of the benefits of the skillful application of such strategic and technological excellence?

## THE INVESTMENT INDUSTRY

In 1990, the investment and asset management industries looked antiquated compared to today. Total assets under management by commodity trading advisers were $10.5 billion. As of March 2007, total assets were $172 billion and growing at an unprecedented rate. This represents a growth of more than 1,600 percent in the last 17 years. In 1990, the CTA industry was primarily an American industry. While it is still domestically dominated, there is an appreciable number of European CTAs that are active today. This globalization of the CTA is very likely to accelerate.

The number of hedge funds and assets under management have both enjoyed an ever-greater explosion. Hedge funds numbered 610 in 1990. As of 2005, they numbered 8,661. Total assets under management by hedge funds in 1990 were $40 billion. Now it is in excess of $1 trillion. That is more than a 25-fold increase.

There has been a similar growth in mutual funds. In 1990, there were approximately 3,100. Today there are over 8,600. Assets under management then were slightly in excess of $1 trillion. Today, it is in excess of $10.4 trillion.

During this time of staggering increase in professional money management, the number of individual traders and investors has remained largely the same.

Another development is that of the proprietary trading shop. Whereas the larger trading firms such as Salomon Brothers. (Remember them? They are now part of Citigroup.) Goldman Sachs and Morgan Stanley have always made proprietary trading a significant part of their operations. “Prop trading” (as it is now affectionately called) has become a considerably more significant part of trading. Even relatively insignificant brokerages have prop desks. There are also a significant number of firms, small, medium, and large, dedicated solely to prop trading. With the trading floor becoming a thing of the past, and electronic trading

and traders filling this gap, the prop trading firm has taken on a new meaning.

What does this all mean? It means many things, but perhaps the two most significant observations are that the bulk of trading capital is firmly in the hands of a professional class of trader and the efficiency of the markets has never been higher and this efficiency will only continue to improve.

Another very significant development in the world of trading is that trading, now more so than ever before, is perceived as the fastest way to achieve great wealth. For the last two years running, the top earning CTA/hedge fund managers have earned in excess of $500 million in a year.

What does that mean? As never before, trading attracts the very best and the very brightest. One needs to question the societal impact of a significant proportion of a generation’s intellectual elite being drained by an essentially nonproductive activity. This is especially significant in light of the large and increasing number of world-threatening crises facing the world today.

It also means that the resources that have been and will continue to be dedicated to the pursuit of trading advantage and profit will become increasingly vast. And when we consider the billions upon billions of dollars currently dedicated to this pursuit, this is a somewhat daunting concept. That the brightest minds are employing vast resources to exploit trading profits means that trading has become and will continue to become increasingly difficult. The markets will continue to become more and more efficient and perhaps exhibit some new behaviors as a result. And as a result of this, new trading opportunities will develop, and the game goes on.

# TRADING STRATEGY DEVELOPMENT TOOLS

To say there has been a significant proliferation of tools available to the trading strategist today compared to the early 1990s would be a dramatic understatement. In 1990, there were three major technical analysis and trading strategy development software applications: *Advanced Trader, Metastock* (and very limited in those days), and *SystemWriter* (which evolved into *TradeStation*).

To get an idea of where we at are today, we need only to review the Traders' Tips monthly feature in *Technical Analysis.* There we find scripting code from nine different applications. And this is just the tip of the iceberg. There are any number of higher-end applications geared toward the professional trader. Of course, there are also the general-purpose applications such as Excel, Mathematica, and Matlab (the latter two widely used by professional trading houses). There is even a programming language called *R,* which has been constructed for those focused on mathematically oriented applications. There is also the ever-present Visual Basic in its various flavors, which is also widely used in professional houses because of its ability to create applications relatively quickly and without a tremendous need for sophisticated programming abilities.

Without belaboring this point, clearly there are many more choices available to the trading strategist these days. Yet this very proliferation presents the strategist with both an obstacle and an opportunity. More on this in Chapter 4: The Strategy Development Platform.

This, of course, says nothing about the vast plethora of add-in products and other more specialized tools that exist now and did not circa 1990. There are hundreds of add-ins for Metastock, TradeStation, and TradersStudio.

These add-ins range in functionality from trading strategies and indicators to those that extend the capabilities of the host product such as those that do a rudimentary form of portfolio analysis.

This also says nothing of the more specialized tools that provide the strategist the ability to create neural net trading applications, perform genetic algorithms to trading strategies, do fractal analysis of the markets, and apply sophisticated data-mining capabilities to trading strategy issues.

Yet this vast proliferation of trading strategy development applications, add-ins, and advanced technological trading applications is a bit of an illusion. Yes, one can purchase and use all of these different products if one is so inclined. But try to tie it all together into a seamless and functional trading application and one sees wherein the problem lies. It is nearly impossible to do so.

Where is the application that lets the strategist design, create, and apply her own custom genetic search algorithm to a Walk-Forward Analysis of a trading strategy that employs an autoregressive integrated moving average (ARIMA) forecasting model of volatility, a neural net that predicts the magnitude and direction of tomorrow's close change, which auto-adapts to market conditions and has a genetic algorithm that balances one's portfolio automatically, strangling models trading stagnant markets with a strategy that is losing in the last year and feeds the strategies that are profiting unusually well and markets that are really moving?

Why is this important? Yes, such a trading platform would be quite sophisticated. These technologies all exist now, however, and did so in the 1990s, too. The computer hardware is now up to the task. There are strategists who can design and create applications like these and even more

sophisticated ones, at that. Yet, the trading strategy development application that would make such a thing possible does not yet exist (at least to my knowledge and I am always looking). One might ask, so what? That, however, would be a rather uninformed question. For the existence of such a trading strategy development application with the ability to integrate and apply such technologies at a usable speed would really be a development that would be at least somewhat in proportion to the vast explosion of computer hardware that we have seen over the last 15 years.

You can count on the fact that if one of the large prop trading firms desires to apply a trading approach as complex—or vastly more so—as what has been mentioned, they have the resources to pull it all together to create and trade such a trading model.

The point is that this capability should be available to the average trader and investor too. The capability is there. The leading trading strategy development software application vendors have been complacent— perhaps they just lack imagination—in the extreme. Part of the problem here as always been that most of the developers of the trading strategy development applications do not have a trading background; as such, they are not as driven by trading profit as traders are to continuously seek out cutting edge technology that can provide the trader with an edge. And the trading community at large, primarily the individual trader and investor, has been willing to accept this sorry state of affairs. Perhaps they too lack imagination... ?

## THE RISE OF ADVANCED MATHEMATICAL CONCEPTS IN TRADING

In the last 15 years, traders have been exposed to a broad horizon of advanced mathematical concepts. For the

individual trader, this has been more in the form of hearsay and less in the form of concrete application. Again, it is a case of the haves versus the have nots.

Morgan Stanley had the resources to hire the head of the mathematics department of Columbia University, David Shaw, and appoint him head of quantitative trading and provide him with the staff, computers, programmers, and other resources to apply his advanced mathematical concepts to trading.

## D.E. Shaw & Company

He is among the best. He went on to form his own top trading firm and now hedge fund D.E. Shaw. His firm, although far from a household word and not a name even known to many traders, routinely do 10 percent of the volume on the New York Stock Exchange in search of small profits on huge transactions exploiting very hard-to-detect (for the average trader) miss-pricings (as they are now affectionately called by the new generation of “quant traders”) of various sorts.

## Renaissance Technologies Corporation

Chances are you haven’t heard of Jim Simons or of his operation Renaissance Technologies Corporation. Since its inception in March 1988, Simons’ flagship $3.3 billion Medallion fund has amassed annual returns of 35.6 percent, compared with annual returns of 17.9 percent for the Standard & Poor’s 500 index. Gross or net, Simons may very well be the best money manager on earth.

“Jim Simons is without question one of the really brilliant people working in this business,” says quantitative trading

star David Shaw, chairman of D.E. Shaw, which boasts returns above 50 percent this year. He is a firstrate scholar, with a genuinely scientific approach to trading. There are very few people like him. Simons surrounds himself with like minds. The headquarters of Renaissance, in the quaint town of East Setauket on New York's Long Island, resembles nothing so much as a high-powered think tank or graduate school in math and science. Operating out of a one-story woodand-glass compound near SUNY at Stony Brook, Renaissance, founded in 1982, has 140 employees, one third of whom hold PhDs in hard sciences. Many have studied or taught in Stony Brook's math department, which Simons chaired from 1968 to 1976.

## Prediction Company

"Founded in 1991 by Doyne Farmer, Norman Packard, and Jim McGill, Prediction Company quickly set out to take the financial world by storm. Based on their earlier work in chaos theory and complex systems, Drs. Packard and Farmer felt the financial markets were an example of a highly complex system that would be amenable to predictive technology. They assembled a team of world-class scientists and engineers to attack the problem.

In 1992, Prediction Company signed an exclusive five-year deal to provide predictive signals and automated trading systems to O'Connor and Associates, a highly successful Chicago-based derivatives trading firm. In 1994, O'Connor was purchased by Swiss Bank, one of the world's largest banks. Swiss Bank extended the exclusive relationship with Prediction Company for another two years. In 1998, Swiss bank and UBS merged to create the world's third-largest financial institution."[2] Prediction Company continues its ground-breaking work with UBS AG.

Why is all of this important? There are any number of reasons. Perhaps first and foremost is proof of the concept that advanced mathematical concepts correctly applied to trading can produce tremendous profit and risk-adjusted returns. Second, and perhaps equally important, is proof of concept of the tremendous effectiveness of advanced knowledge and technology when coupled with resources sufficient to harness this technology to trading.

The dance continues.

## TRADING MEETS HIGHER EDUCATION

In 1990, I still considered myself fortunate to find a good book on trading. Do a job search today for trading openings and you will find hundreds of job listings for people trained in financial engineering. The circa-1990 trader asks, “What is that?”

No coincidence is the existence of graduate level training in stochastic calculus and financial engineering and the amazing success of super-quants like David Shaw, Jim Simons, and Doyne Farmer.

If one looks at the history of these developments, one can easily trace its beginnings to an extremely important discovery by the creator of fractal geometry, the mathematical genius Benoit Mandelbrot. He discovered that the distribution of price changes in financial markets follows a fractal distribution, not the standard Gaussian distribution assumed by all financial mathematicians and which is embedded in things like the Black-Sholes options pricing model. This is an earthquake. To a certain extent, I am really not too sure that this is understood or applied by all financial engineers even today.