Chapter 1

Introduction
DECISIONS AND UNCERTAINTY

Most of the decisions we make in life are choices that involve weighing opportunity against risk. Most of the calculations are extremely complex and involve estimating costs and values of things not easily quantified—where to live, whom to marry, what employment to pursue. All are specific applications of making decisions under uncertain conditions. It seems that the more important the decision, the less opportunity we have to practice and the more important it is to be correct early in the process.

How we handle our finances is certainly an important area, and one where we don’t get many practice runs. For traders, the goal is maximizing trading profits while minimizing the risk of bankruptcy. In the spectrum of life’s activities, this is a problem that is relatively easy to quantify and analyze. The major aspects already have easily measured units of value—dollars. And, given a little understanding of probability and statistics, along with some computer data analysis, we can outline a plan.

OVERVIEW

This book was written to help answer questions that I regularly receive from colleagues and clients. The form of the comments and questions are along the lines of:

- Developing trading systems that pass tests of statistical significance when applied to out-of-sample tests is hard.
- What can I expect when I begin trading this system?
- Am I trading the right issue with the right frequency?
- What are the characteristics of high-growth trading systems?
- How large a trading account do I need?
- What are my year-to-year returns likely to be?
- How long will it take me to reach my retirement goals?
- How likely am I to lose a significant portion of my money?
- How can I tell when the system is broken?
- Should I use aggressive position sizing?

These questions are at the heart of “trading as a business.”
I see a progression of stages of maturity of technically-oriented traders and system developers.

- Keeping funds in a savings account.
- Buying and holding stocks and mutual funds on an ad hoc basis.
- Buying stocks or mutual funds on the advice of a broker or advisor.
- Looking at charts of price and volume, and trying to identify meaningful patterns.
- Using support and resistance levels and percent drawdown to manage positions.
- Learning about formula-based trading systems, moving averages, trailing stops.
- Deciding to move from discretionary to mechanical systems.
- Designing trading systems and coding them in an analysis platform’s language.
- Backtesting trading systems.
- Optimizing trading systems.
- Selecting a personal objective function and choosing among alternative systems.
- Performing walk forward runs and analysis of out-of-sample results.
- Learning about statistics and validation.
- Learning about risk – market risk, holding period risk, trade risk, portfolio risk, account risk.
- Learning about utility function and personal risk tolerance.
- Setting personal account management goals.
- Performing Monte Carlo simulations.
- Applying statistical measures to trading performance.
- Determining risk levels, setting position size, analyzing likely account performance.
- Managing wealth – staying liquid – quitting when goals have been met and while ahead.

This book assumes that the reader understands trading system design, testing, and validation, has developed trading systems that appear to be profitable (have positive expectancy) when tested on out-of-sample data, and is ready to work further in modeling trading system performance.
Key topics of the book include:

- Trading as a business
- Trading versus investing
- Liquidity
- Background in probability
- Background in gambling
- Comparison between gambling and trading
- Application of probability to trading
- Background in Monte Carlo simulation
- Application of Monte Carlo simulation to trading
- Utility of money
- Measuring risk
- Risk of ruin
- Comparison of trading systems
- Variability in trading results
- Absorbing boundaries – retire or ruin
- Managing risk
- Drawdown estimation
- Account size determination
- Background in position sizing
- Comparison of position sizing methods
- Use of leverage
- Planning to retire
- Statistics for traders
- Do it yourself tools

The emphasis is on:

- Understanding what is predictable and what is not
- Understanding variability and risk
- Characteristics of trading systems
- Monte Carlo simulation
- Trading as a business
- Realistic estimates of equity growth

The book is independent of any specific trading system development platform. Most of the analysis is done in Microsoft Excel. No expensive
software is required. Spreadsheet formulas are provided, links to tools used are listed, and an extensive bibliography is provided.

**INTENDED READERS**

This book makes extensive use of probability and statistics. Achieving meaningful results requires a relatively large amount (typically one hundred or more data points) of clearly quantified trading data – usually in the form of closed trades, or daily or weekly equity balance. And there is a little algebra.

Traders or investors whose methods are based on chart analysis or other non-quantifiable methods will probably have difficulty producing the trading data that is required for the statistical analysis described in this book. Formula-based analytical methods lend themselves much better to producing trade results that are used both to establish trading baselines and estimate future performance.

Traders who use bars shorter than one minute and who hold for less time than a few minutes fall into the category of high frequency traders. High frequency traders use high speed computers running sophisticated analytical trading algorithms, high bandwidth communications lines, with offices and computers physically located close to the trading venue. They are backed by large, well financed operations. Their bids and offers are posted for less than a second and are often cancelled and replaced many times before being filled. Their positions are held for short periods – from less than a second to several seconds. They expect to make a profit of less than one cent per $100 traded. They always pay very low commissions, and may receive payment if their trades add liquidity to the market. They account for 50 percent or more, depending on the reporting source, of trading volume in 2010. That percentage is up from single digit amounts a few years ago, and rising.

Traders or investors who use monthly bars and those whose holding period is longer than a few months, even if their methods are fully quantified, will have difficulty generating enough data to establish baselines and to validate their trading systems. Investors who base their decisions on economic or corporate fundamentals will find nothing related to their methods in this book, other than illustrations of increased risk associated with long holding periods. I have written a paper entitled “Use of fundamental data for active investing in US equities” that explains my reasons for thinking that fun-
damental data has no value. You can download a free copy from http://www.blueowlpress.com/activities.html

This book is intended for traders who use analytical methods to buy and sell stocks, futures, ETFs, mutual funds, and options; whose trades typically last between a few minutes and a few months; and whose analysis is based on price bars that range from one minute to one week.

The language and terminology used in analyzing trading systems is shared with that of probability, statistics, information theory, game theory, and gambling. Some in the investment industry will term what is being discussed here as speculating or gambling. And some readers may object that the treatment of trading is not clearly differentiated from gambling. Although some authors try to make a clear distinction, I do not believe it is possible. John Kelly, working with Claude Shannon on information theory and communications for Bell Laboratories in 1956, gave us the Kelly formula which relates the probability of winning to the optimal size of a bet. A few years later, Shannon introduced Kelly and Ed Thorp, resulting in Thorp’s book, Beat the Dealer, which showed the practical application of the Kelly formula to blackjack. Later, Thorp successfully applied his techniques to the stock market. Terms such as win to loss ratio, reward to risk ratio, risk of ruin, odds, probability, and bankruptcy are common to both fields. Whether we feel trading and gambling should be closely associated or not, they are associated, and this book does not make a strong effort to separate them.

There is one very significant difference between gambling and trading. In gambling, the house almost always has a sizable advantage. Well designed trading systems give an advantage to the trader. This book discusses ways to recognize that advantage, measure the associated risk, capitalize on the advantage, and analyze trading as a business.

While this book is not intended to describe trading systems, many of the examples used are actual trades that were made with real money by real people whom I personally know. The markets are clearly not efficient. This book helps you capitalize on that.

**Overview of the Monte Carlo Technique**

A set of trade results or an equity curve, even when they are truly out-of-sample or actual trades, contribute one data point toward a statistical analysis. We will make several assumptions about the future, all based
on the best and least biased information we have. In order of preference, the best data would be actual trades made with actual money, then paper trades, then trades resulting from out-of-sample and walk forward runs. If in-sample data is used, the analysis will over-estimate the likelihood of success and under-estimate the likelihood of failure – perhaps by a very significant amount.

In setting up a Monte Carlo simulation, we will:

- Assume that the system continues to identify profitable trades in the future as well as it did over the period sampled.
- Assume that the conditions over the reported period are representative of the future – there will be periods of rising prices, falling prices, high volatility, low volatility, and so forth, but they will be similar to those covered by the period sampled.
- Assume that future trades will have the same characteristics in terms of trading frequency, ratio of win to loss accuracy, profit factor, maximum adverse excursion, maximum favorable excursion, and so forth.

But what we cannot assume is that the order of periods of market condition continues unchanged. That is, we cannot assume that future trades occur in the same sequence as they did in the reported period.

Monte Carlo simulation gives a practical and statistically sound technique for estimating future trading results. It involves repeatedly choosing trades from the list of sample trades at random and creating a simulated trading history. From that sequence, we can generate a summary of trading results, and an equity curve with drawdown calculation. Each simulated equity curve contributes one data point to the analysis. In fact it is possible that one of the sequences is exactly the original sample data in the original sequence and gives exactly the same equity curve. This point is important and bears repeating – the set of trade results and equity curve that results from a backtest, or even from a single simulation run, contributes a single data point toward the analysis of the performance of a trading system. After running many rearrangements, the distribution of likely results can be determined.

Using data randomly and repeatedly chosen from a statistical distribution is central to the Monte Carlo simulation technique. Chapter 6 gives background on the technique and later chapters give detailed examples of its application.
DETECTING SYSTEM BREAKDOWN

A regularly heard question asks what happens if the future fails to behave as the past. The answer is that the projected distribution will no longer apply. Several sections of this book specifically address techniques that help determine when the actual performance is significantly different than the expected performance. And, in particular, to help determine when the system is broken. As long as the system performs as expected, the distribution describes what might be expected; and when the system stops performing as expected, we can detect that and then modify the trading method.

Throughout this book the projections of day-by-day or trade-by-trade equity, drawdown, and trading methodology will be based on a four year horizon, where each year has 252 trading days. If a system has 20 trades per year, there will be 80 trades in four years, and the analysis will be carried out using sequences of 80 trades. A system that trades twice a year will have eight trades in its four years. An intra-day system that averages two trades per day will have 2016 trades in its four years.

TRADING SYSTEM EXAMPLES

During a recent seminar on trading, several colleagues made presentations describing their trading systems. All had done high quality design, testing, and validation. The data they presented was from out-of-sample tests, including walk forward runs. All data is net after allowing for reasonable commissions and slippage.

Several questions arise at every one of these discussions:

1. Is this system good enough to trade?
2. What is the best way to trade this system?
3. How can I tell when the system is broken?

This book is intended to address these issues – with a little background and theory to justify the approach I recommend, and some practical tools you can use to apply it yourself.

What follows is a brief summary of each of those presentations.
**THE STOCK TRADER**

She has developed an indicator that gives signals that a stock is over-extended, either relatively too high in price or too low, and is likely to revert to the mean soon. She has a margin account with $100,000 in cash and is willing to use an additional $100,000 in margin funding.

The characteristics of her system are:

- Uses end-of-day data.
- Computes signal points in advance.
- Uses limit orders to enter and either limit or market-on-close orders to exit.
- Has a profit target.
- Has a maximum holding period.
- Holds one to three days.
- Has directional accuracy greater than 70 percent.
- Trades highly liquid US common stocks.
- Trades both long and short, although only the long side is shown here.
- Is 100 percent mechanical.
- Has about 220 long trades per year.

Since prices of individual stocks are highly correlated, there are periods when up to five positions are held, and other periods with no holdings.

The summary of trades that follows is based on a constant position size of $10,000 per trade. This may not be the appropriate method to trade this system, but it is appropriate when gathering information necessary to perform the analysis. Since five positions, each of $10,000, total less than her trading account, she could use this method in actual trading.

AmiBroker software was used to design, test, and validate the trading system. Figure 1.1 shows the summary of the test run that produced the sample data used in the Monte Carlo simulation. AmiBroker is also used to compute the signal points in advance for use each day.

While AmiBroker was used in this example, the analysis throughout this book is independent of the development platform used to generate the trades.
### Figure 1.1

<table>
<thead>
<tr>
<th>Statistics</th>
<th>All trades</th>
<th>Long trades</th>
<th>Short trades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial capital</td>
<td>100000.00</td>
<td>100000.00</td>
<td>100000.00</td>
</tr>
<tr>
<td>Ending capital</td>
<td>157441.93</td>
<td>157441.93</td>
<td>100000.00</td>
</tr>
<tr>
<td>Net Profit</td>
<td>57441.93</td>
<td>57441.93</td>
<td>0.00</td>
</tr>
<tr>
<td>Net Profit %</td>
<td>57.44 %</td>
<td>57.44 %</td>
<td>0.00 %</td>
</tr>
<tr>
<td>Exposure %</td>
<td>20.25 %</td>
<td>20.25 %</td>
<td>0.00 %</td>
</tr>
<tr>
<td>Net Risk Adjusted Return %</td>
<td>283.60 %</td>
<td>283.60 %</td>
<td>N/A</td>
</tr>
<tr>
<td>Annual Return %</td>
<td>12.10 %</td>
<td>12.10 %</td>
<td>0.00 %</td>
</tr>
<tr>
<td>Risk Adjusted Return %</td>
<td>59.76 %</td>
<td>59.76 %</td>
<td>N/A</td>
</tr>
</tbody>
</table>

All trades: 689 689 (100.00 %) 0 (0.00 %)
Avg. Profit/Loss: 83.37 83.37 N/A
Avg. Profit/Loss %: 0.83 % 0.83 % N/A
Avg. Bars Held: 4.62 4.62 N/A

Winners: 529 (76.78 %) 529 (76.78 %) 0 (0.00 %)
Total Profit: 110117.09 110117.09 0.00
Avg. Profit: 208.16 208.16 N/A
Avg. Profit %: 2.08 % 2.08 % N/A
Avg. Bars Held: 3.45 3.45 N/A
Max. Consecutive: 33 33 0
Largest Win: 728.84 728.84 0.00

Losers: 160 (23.22 %) 160 (23.22 %) 0 (0.00 %)
Total Loss: -52675.15 -52675.15 0.00
Avg. Loss: -329.22 -329.22 N/A
Avg. Loss %: -2.29 % -2.29 % N/A
Avg. Bars Held: 0.48 0.48 N/A
Max. Consecutive: 10 10 0
Largest Loss: -1746.26 -1746.26 0.00

Max. trade drawdown: -2108.61 -2108.61 0.00
Max. trade % drawdown: -20.91 % -20.91 % 0.00 %
Max. system drawdown: -9151.49 -9151.49 0.00
Max. system % drawdown: -7.71 % -7.71 % 0.00 %
Recovery Factor: 6.28 6.28 N/A
CAGR (MaxDD): 1.57 1.57 N/A
RAI (MaxDD): 7.75 7.75 N/A
Profit Factor: 2.00 2.00 N/A
Payoff Ratio: 0.63 0.63 N/A
Standard Error: 5689.34 5689.34 0.00
Risk-Reward Ratio: 2.14 2.14 N/A
Ulcer Index: 2.10 2.10 0.00
Ulcer Performance Index: 3.19 3.19 N/A
Sharpe Ratio of trades: 2.06 2.06 0.00
K-Ratio: 0.0774 0.0774 -1.42ND

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This document is a chapter of "Modeling Trading System Performance"
Published by Blue Owl Press, Inc.
www.modelingtradingsystemperformance.com
The 689 trades are sorted and placed in bins, each $10 wide. Figure 1.2 shows the resulting histogram. 216 of the trades exited at a profit target and had $290 profit.

![Histogram of Profit Frequency](image1.png)

**Figure 1.2**

Figure 1.3 shows the equity curve from the backtest. Initial equity is $100,000. Each trade was made taking a $10,000 position.

![Equity Curve](image2.png)

**Figure 1.3**
1. **Is this system good enough to trade?**

Based on the summary and the single backtest equity curve shown above, the system looks very promising. One hundred equity curves, each covering a four year period, were generated using Monte Carlo simulation.

Ten of them were plotted together in a “straw broom” chart which is shown in Figure 1.4. The dotted line is the average of the ten. Note how each begins with $100,000 in equity, but the paths are different as trades occur in different order. Final equity after four simulated years of trading can be read from the right-hand edge. Drawdown can be estimated as equity curves drop from recent highs.

![Equity Curves for 10 Simulation Runs](image)

**Figure 1.4**

The 100 results have been used to create a chart showing the probable distribution of final equity. It is shown in Figure 1.5. The midpoint of the distribution is $157,654. That is about 12\% compound annual rate. The system is exposed only about 20\% of the time, so the effective risk adjusted rate is about 60\%, assuming there are equally attractive opportunities from other trading systems while this system is in cash.

Note that about 5\% of the simulation runs resulted in a final equity of $143,913 or less, and about 5\% resulted in a final eq-
uity of $171,357 or greater. While any of these results at the 5% level are unlikely, they could occur and still be consistent with proper operation of this system.

Later chapters have detailed descriptions explaining how these charts are created and interpreted. You can do it yourself using Excel and tools that are free.

![Figure 1.5](image)

The same 100 results have been used to create a chart of the probable distribution of maximum drawdown. Expected drawdown, that is the drawdown measured at the 50% point of the range of simulation results, is $3,113. If future performance follows the distribution of trades, drawdown will be less than $3,113 about half the time and greater about half the time. 5% of the time—one four-year period out of 20—drawdown will exceed $4,972. See Figure 1.6.
Everyone in attendance agreed that this system is good enough to trade.

2. What is the best way to trade this system?
   Some alternatives are:
   - Trade a single unit of $10,000 at each signal. The results are those shown in the figures just above.
   - Trade a fraction of the account balance on each trade. With $100,000 in cash and an equal amount in margin funds, she has $200,000 available. Her holdings will vary between all cash and five positions. Based on her cash holding, she can use from 0 to 40% of her cash for each position.
   These, and other options, are discussed in later chapters.

3. How can we tell when the system is broken?
   To answer, compare recent performance with a benchmark. A logical candidate to be the benchmark is the sample data from the period used to set up the Monte Carlo simulation runs. Comparisons that are meaningful and easy to make are:
   - Compare the mean profit (or some other meaningful metric) of recent trades with the mean profit of the benchmark.
This tests whether recent trades are different than the benchmark sample.

- Compare the mean profit of recent trades with random performance. This tests whether recent trades are better or worse than breakeven.
- Compare the accuracy of recent trades with accuracy of the benchmark.

Systems with high accuracy are easy. This trader's accuracy is 76 percent. If she has 5 or fewer wins in any 10 trade sequence, the system is probably broken. Similarly, 9 or fewer wins in 15; or 13 or fewer wins in 20. Each of these conditions is expected to occur by chance less than 5% of the time. (See Chapter 11 for charts showing these values and for formulas that can be used with any combination of length of sequence and accuracy.) Since she has about 700 trades in four years, and there are 691 10-trade sequences in that period, then she will observe 5 or fewer wins in a 10 trade sequence and think the system is broken about 34 times, or about once a month. (But expect these 34 to come in groups, rather than spaced evenly at one per month.) As is explained in greater detail in later chapters, her response should be to stop taking trades with real money, but continue to track performance. When performance returns to within the expected parameters, she should resume making real trades. If it never returns, she is safely in cash and not trading a broken system.

**The ETF Trader**

This system models and trades SPY, the Exchange Traded Fund based on the S&P 500 index. The trader has $100,000 in a margin account and is willing to use an additional $100,000 of margin funding. He has permission to trade futures and options in the account.

The characteristics are:

- Computes indicators and signals prior to the close each day.
- Trades Market On Close – MOC.
- Holds exactly one day.
- Uses no stops and no profit targets.
The system is always in the market, either long SPY or short SPY. A four year period that establishes the benchmark, each trade being made with a single unit of $10,000.

The trader felt that he could risk losing up to 40% of his initial stake, $40,000. But if he experienced a drawdown of $40,000, he would have to stop trading the system. His goal was to increase the account to $400,000, at which point he would stop trading, withdraw his money from the market, and retire.

This trader has more alternative ways to trade than the stock trader. He can:

- Model SPY, trade SPY with a position size of a single unit of $10,000 per signal.
- Model SPY, trade SPY with a position size that is a fraction of the account equity on each signal.
- Model SPY, but take trades in leveraged ETFs, such as SDS or SSO.
- Model SPY, but take trades in a futures contract, such as ES.
- Model SPY, but take trades in one or more common stocks that are closely correlated with SPY, such as AMG, LUK, or UTX.
- Model SPY, but take trades in options – options on SPY, on ES, or on common stocks.

Later chapters go into detail about these alternatives.

He demonstrated a system that was about 53% accurate in predicting whether the next close will be higher or lower than the one when the position is taken. He was interested in determining what level of accuracy produced what results.
Figure 1.7 shows the straw broom chart of ten simulation runs.

A single backtest could produce any one of these equity curves. Based on some of them, the system looks profitable but with high drawdowns. Based on others, the system is not profitable.
Figure 1.8 shows the distribution of the final equity. The average final equity of the 100 simulation runs is $165,818. That is about a 13% annual compound rate for the four years.

Figure 1.9 shows the distribution of the drawdown. Over 92% of runs had drawdowns over at least $40,000. The expected drawdown is $60,284. There is a greater than 10% probability that the drawdown will exceed $100,000. In this study, drawdown was measured in absolute dollar amounts. If the trader relaxes his requirement, say to 40% of maximum equity, the drawdown limit will be reached less often.
The class was understandably uncomfortable with these results. An accuracy level of 53% is clearly not high enough. The distribution of 100 runs shows how high the risk really is.

Later chapters explore accuracy in more detail, including more charts, guidelines, and do-it-yourself tools. We will see that higher accuracy both increases the return and decreases the risk. A system that predicts the direction of the one day change in SPY with sufficient accuracy is very desirable. The wide variety of alternatives for trading such a system further increases its value.

**THE FUTURES TRADER**

The woman who presented this system is interested in trading agricultural commodities, including corn, wheat, and oats. She is using trend-following methods, such as the crossover of two moving averages, to take either long or short positions. Her characteristics are:

- Uses daily data.
- Pre-computes the price at which a cross will take place.
- Monitors the markets during floor trading hours.
- Takes positions at the market price when the cross takes place.
For the simulation, each position is one contract. Using a well defined unit, and taking all positions in single unit size, is important in establishing simulation baselines.

The average profit is $117 per contract per trade. The average trade is held six days. Figure 1.10 shows the summary of trades.
Introduction

The system did poorly for the first 18 of 48 months. While the final 30 months look good, it is important to use all of the data to establish the trade distribution for the simulation. Figure 1.11 shows the equity curve from the out-of-sample test.

Figure 1.11

Figure 1.12 shows the straw broom chart.

Figure 1.12
Figure 1.13 shows the final equity. There is a small probability of no gain over the four year period.

![Figure 1.13](image1.png)

Figure 1.14 shows the probability distribution of drawdown. Drawdown at the 50% point in the distribution is $9,725. There is a 5% probability the drawdown will be $15,700 or greater.

![Figure 1.14](image2.png)
Most participants did not like this system as it was traded.  
- The winning percentage is low – only 38%.  
- Midpoint of the final equity is $125,850 – an annual compound rate of return of less than 6%.  
- Midpoint of the drawdown is $9,725, with 5% probability of $15,700 drawdown.  

Class members felt the ratio of expected drawdown to expected reward was too low, and risk of a large drawdown was too great.

These results are trading a single corn contract in a $100,000 account.  At the time this is being written, initial margin on corn is $2,025, and maintenance margin is $1,500. Some rules of thumb suggest determining the minimum account size by adding the drawdown that is 95% probable to twice initial margin, which would be $19,750 in this case. Trading one contract for every multiple of $19,750, would allow 5 contracts for the $100,000 account. In that case, the CAR would be about 30%.

**Fractional Position Sizing**

This system lends itself well to analyzing position sizing that risks a fraction of the account balance on each trade.

A series of simulations, each 1000 runs, was run using values of f, the fraction to risk, from 0.01 to 0.40.

Risk per contract was set to be $2,000, slightly more than the largest loss of the 220 trades, which was $1,975.

To calculate the number of contracts to be taken on the next trade, multiply the current account balance by f. Divide that amount by $2,000, then round down to the next integer to obtain the position size. Fractions of 1% and 2% were too small to allow any trades. One of the output columns from the simulation was the maximum number of contracts. Using fraction 0.03, 53% of the runs used at most 1 contract, 44% used 2 contracts, and 3% used 3 contracts.

Figure 1.15 shows the terminal wealth at the 50% point of each set of runs. Terminal wealth, or terminal wealth relative, TWR, is the multiple that the final account balance is of the initial account balance. A terminal wealth of 2.0 means the account doubled in four years. The
jagged line connects the points determined from the simulation runs. The smooth line is a 2nd degree polynomial best fit to the experimental data. The peak occurs at a fraction of 0.24. An independent calculation based on the geometric mean of the trades suggests it is 0.235. The value of \( f \) at the peak is the optimal \( f \)—that fraction that results in the highest terminal wealth.

**Figure 1.15**

Figure 1.16 shows the distribution of final equity for a fixed fraction of 0.24. The terminal wealth at the 50% point is 4.16. About half the time equity after four years will be greater than 4.16 times initial equity; about half it will be less. The vertical scale is limited in order to show detail in the midrange. There is a high probability of a very high terminal wealth.
Figure 1.16 focuses more closely on the left side of the distribution. It shows there is about a 20% chance there will be no net gain after four years, and a 5% chance of a loss of more than 70% of the trading account.
Figure 1.18 shows the distribution of the closed trade drawdown at a fraction of 0.24. At the 50% point, drawdown is 74% of maximum equity. 5% of the time drawdown will exceed 91%.

![Corn Futures -- Fraction = 0.24 -- Drawdown](image)

**Figure 1.18**

Figure 1.19 shows the distribution of drawdown for the range of fractions. The dotted line shows the drawdown at the 95% level; the solid line at the 50% level. Note the vertical line at 0.24 and compare the values of drawdown at 50% and 95% to figure 1.18.

The circles at points A, B, and C help identify more prudent fractions. If the trader is willing to take a 50% risk of a 40% drawdown—Point A—he can use a fraction of 0.10. Note that he risks a 5% chance of a 60% drawdown—Point B. A safer fraction is 0.06, which shows a 5% chance of drawdown no worse than 40%—Point C.
Figure 1.19

Figure 1.20 shows the distribution of final equity when traded at a fraction of 0.06. The midpoint of terminal wealth is 1.87. There is a 9% chance of no gain, and a 5% chance of quadrupling the account.
Figure 1.21 shows the distribution of drawdown when traded at a fraction of 0.06. The midpoint is a drawdown of 23%. There is a 5% chance the drawdown will exceed 38%.

When traded at a fraction of 0.06, the midpoint of final equity is 1.87, which is a CAR of about 17% for the four years. With the midpoint drawdown at 23%, this system is more reasonable. One of its drawbacks is the accuracy ratio of only 38%, which makes it difficult to tell when the system begins to break down.

Later chapters expand on these studies, and explain how you can perform similar analysis on your data.