Trading Systems

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Chapter 1

Introduction

Trading systems are really an interesting distributed system. The entire world's financial marketplace is a loose connection of computer systems operating almost completely autonomously with no general architect, no central organization, and highly interconnected.

The use of the Financial Information Exchange protocol has allowed this massive distributed system to function well enough that bugs and such are not expected to affect the valuation of nearly everything in the economy. As such, financial engineers are required to understand what it means to contribute to the world's financial markets without disrupting orderly trading.

This book is written to help facilitate everything that is necessary to understand in order to build a trading system that has minimal likelihood of disrupting orderly trading while maximizing commercial value. Unfortunately, "disrupting orderly trading" is insufficient as an engineering specification. This book attempts to tease out the engineering concerns around maintaining orderly trading while providing maximal value.

But, beyond the finance, there are engineering tradeoffs as well. This book discusses the nature of failures in distributed systems and how they manifest in trading. It also discusses how, and, most importantly, when, to make engineering decisions. It discusses the major engineering concerns for a variety of common trading systems and the tradeoffs for each. The patterns expressed may yet still evolve as people learn how to diversify liquidity. The goal is to instruct the engineer that diversification can be managed through natural organic business growth and to provide some patterns to apply in selecting technology to meet the requirements.

Of course, alpha decays. Strategies rotate. Success is diversified. Change is the nature of the business. There is no single trading system that can do it all. But, given enough pieces of a trading system, you can make a trading system that does neary everything. And, that is where the flexibility happens.

Decomposition of the trading into systems that can be interconnected and swapped around provides for very flexible trading environments. The goal of this book is to discuss the major responsibilities of a complete trading system,

review how these responsibilities can be encapsulated,

Part I

Theory

Chapter 2

The Three Trading Systems

One simple way to classify trading systems is by the type of instrument they trade. Equitites engines, futures engines, and currency/crypto trading are some examples of types of trading engines. But, defining instruments turns out to be a very difficult problem and one reserved for another book.

Rather, we can look at the type of *risk* the instrument being traded represents. There are three fundamental types of risk that most, if not all, instruments fall into:

1. *Absolute risk instruments* are instruments where it is *not possible* to lose more than the principal on the instrument.

2. *Relative risk instruments* are instruments where it is *possible* to lose more than principle on the instrument.

3. *Cross risk "instruments"* are not really instruments at all. These are crossrates that compute the value of one thing in terms of the other. EURUSD, for instance, is how many dollars it takes to buy 1 euro. There is no "EURUSD" instrument. When I refer to instruments in this book, I inclusively include crossrates and crypto trading, even though these are not instruments by any definition.

At the heart of these definitions is the idea of risk. Throughout this book, I will measure risk in dollars. Value at Risk (VaR) or appropriate surrogate is the idea being captured. Some idea of the magnitude of the first derivative is another way to conecptualize this. But, to measure risk, we need to understand another concept.

Holding period, or how long should the trading system expect before any particular position is unwound, is the other concept necessary to describe the type of risk being taken on. Given a holding period and a variance, the total amount of *traded risk* can be modeled.

As the trading horizon decreases, the total amount of traded risk that can be accummulated safely decreases. Having a highly volatile short term view is

incosistent with having a large position and expectation of profit. As such, the quantitative trading strategies fundamentally change. The algorithms used to manage portfolios get more and more streamlined. There becomes a very real tradeoff between performance and flexibility. For this reason, trading systems can be divided into three different holding horizons based on focus.

1. *Mid-long frequency* strategies routinely hold informed overnight positions. By informed, I mean exactly that, the trade was designed to incur overnight volatilies. Holding times are long enough to make ownership limit positions possible for long periods of time while less directional trading can still playout intraday.

2. *Low-latency* trading has evolved and added appropriate "ultra" and "super," but their technology has become robust enough and flexible enough that low-latency trading engines are filtering into broader and broader trading strategies. These are mid-to-high frequency trading signals that allow for accumulation intraday and possibility of overnight holding but rely on market making strategies to improve market impact.

3. *Ultra Low Latency* We are almost to the point where there is the minimal entropy inside the switch that triggers the outgoing order. The entire fight is finding clever ways to cut the number of bits required of an incoming message to trigger a profitable trade on the outbound.

These are three very different kinds of trading systems–algorithmic trading at a maximal rate related to traded risk, high speed trading using very narrowly applicable technology, and the hybrid system that blends them. This chapter will explore risk and trading horizon in depth to understand how a trading system

2.1 Risk

Before we start with trading engines, let's start with trading. Why do people trade? The reasons are as diverse as the wisdom or folly behind them. This book is not concerned with *why* people trade but with *how* people trade. Or, rather as the case is today, how computers trade.

For instance, consider a retail order placed on a app that enables day-trading. That order is then presented to a wholesale market maker that will decide whether they should fill from inventory or exhaust. There can be several layers of this exhaust, depending on the calibre of the retail trader and the liquidity of the name being traded. The eventual final exhaust is, of course, the open market. There can be several trading systems tied together in a loose collaboration through FIX that eventually all agree on how to fill the order.

Of course, trading can get much more sophisticated than this. It would be very difficult to give an exhaustive list of the potential responsibilities of a trading system. Not only that, but rules and regulations change fairly frequently around the world. Profitable trading strategies ebb and flow as macroeconomic

conditions gyrate. The trading system should fill orders at *minimal market impact* without impacting orderly trading while being able to seamlessly absorbed changes required by the ever evolving landscape. Should a new marketplace appear desirable, it should be serving that marketplace within a matter of weeks to race opportunity decay.

This is the financial dimension of trading systems. The trading system negotiates the exchange of something of value for something else of value for the purposes of transferring some risk. Exposure to profits and losses of a company, the point value of the S&P 500 will increase or decrease, inflation risk, default risk, etc. The list goes on and on, but the fact remains, all trading incurs risk. All trading systems manage risk. The trading system facilitates the lifecycle transistions of risk.

As such, this book divides these trading systems into three different types of financial instrument: *absolute risk instruments* such as equities, *relative risk instruments* such as derivatives, and *cross risk instruments* such as currency pairs.

A trade can decide to take a risk. The trader can calculate how much risk they would like to take, find an instrument that represents that risk, compute the amount of the instrument to purchase, and enter the trade. At this point, the trader owns rights granted by the instrument. But, the trade won't turn a profit or book a loss until..

2.2 Horizon

They flatten their position. The length of time the trader plans to hold the position before re-evaluation is the *horizon*.

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Chapter 3

Instruments

3.1 Instruments, Porfolios, and Risk

Trading, the primary means of allowing wide spread division of labor, simultaneously privides a service called *price discovery*. These activities are far too complex to try to review here. Rather, we care more about the mechanism by which this takes place. At its heart a trade is simply an exchange of two things by two people. Let's dissect how hard this actually is.

Suppose Alice and Bob would like to trade an apple for a banana. They could simultaneously hand each other the fruit. Otherwise, without an intermediary, there will be an instant in time where Alice or Bob will be in possession of both pieces of fruit. If Alice and Bob were to try to exchange something that didn't fit in each other's hand, then there must be a time of ambiguous possession. This ambiguous possession either involves Alice and Bob simultaneously both or neither in possession of the fruit. This instant of ambiguous possession begins with agreement trade and ends when each party has clear title. What this means is trading large, complicated things only gets harder and more complicated.

One of the most complicated things traded are financial instruments used to invest capital in order to make commercial gains. As you can imagine, the trading that happens here is extraordinarily sophisticated due to how complex the trading needs to be as well as how complex the financial instruments are. This book goes into excruciating detail about how complex trading can get. Understanding how to evaluate the value of financial instruments is left as an exercise for the reader.

What is a financial instrument? Suppose you take a very large problem and divide up paying for the solution among a large number of people because the problem is that large. Well, the people that *invest* in solving this problem are due the relative proportion of any commercial gain achieved by that solution. These little divisions of financing are called financial instruments. At their heart, there is a risk being undertaken that may provide commercial gain. This risk is being divided up and distributed to the investor at a rate commensurate

to how much they invest relative to the total value of the endeavor.

A financial *instrument* is little more than the expression of some commercial or economic risk or other risk that can be measured in currency. The instrument indicates the owner has particular rights and priveleges that have value. The currency exchanged for the instrument is a measure of that value. Not the only measure, as value as a very relative meaning. What one person values highly, another may value cheaply.

Getting at the value of an instrument is rather challenging. It is said that the primary purpose of trade is to "discover the price." This is generally considered to be the price at which the most transactions would take place. The philosophy and practice of trading are left as an exercise for the reader. Suffice it to say, understanding the value of an instrument is at the heart of all trading: two people disagree on the value of an asset owned by one.

The conviction to which the valuation applies, the time horizon on the term of ownership, any number of other considerations also go into the decision. Even the proverbial throwing a dart a the wall can go into the consideration. At the end of the day two things change hands: one is the instrument that represents some risk, tangible or intangible, and *currency* that measures a value.

3.2 The Lifecycle of a Trade

1. Trigger A need to trade has been identified, whatever that need maybe. This need is expressed as a desired portfolio of instruments.

2. Execution

3. Exit

Chapter 4

Markets

We begin by idealizing commerce. At the risk

Part II

Practice