

# A Tutorial on Stock Trading Via Control-Theoretic Methods with Suggestions for Research and Applications

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## Abstract

This tutorial introduces an ongoing line of research involving the use of control-theoretic methods in stock trading. No significant knowledge of financial markets will be assumed and the selection of topics to be covered is strongly biased by the speaker's transformation from theoretician to practitioner over the last decade. Throughout the presentation, in the hope of motivating control community members to get involved in stock trading research, mathematical details will be intentionally deemphasized in favor of big-picture ideas. The tutorial will begin by covering a number of the most common types of buy and sell orders such as market, limit, stop and short. This will be followed by a description of what happens to orders once they arrive at the exchange. To this end, we describe the operation of the so-called "Limit Order Book" which matches up buyers and sellers using data time stamps at the nanosecond level. Finally, this first part of the tutorial will include methods for reformulation of a trading scheme in terms of modern control theory and writing simple Matlab simulation codes which are suitable for numerical simulation.

The most important question arising in the tutorial is the following: To what extent should the trader develop and rely on mathematical models for the evolution of the stock price over time? In this regard, the speaker, having participated heavily in markets, both personally and through his LLC over the last twenty-five years, will emphasize the following point of view to which he has evolved: Stock trading algorithms which rely significantly on price modelling and prediction, especially those based on the abstract tools in financial mathematics such as stochastic differential equations, can be highly unreliable and of questionable worth. Suffice it to say, given the highly nonstationary nature of the market dynamics, control scientists seeking to get involved in stock trading research would be well served by concentrating their efforts on the development of so-called model-free algorithms and associated backtesting—applying their algorithms to a diverse selection of past historical market data to determine what performance would have hypothetically occurred.

With the considerations above in mind, as a "stepping stone" to real-world markets, we first consider the problem of making sequential bets on a biased coin with known probability of heads  $p > 0.5$  and differing well defined payoffs on heads and tails. As explained in tutorial, this scenario corresponds to a highly idealized stock trading problem with the size of the sequential bets  $u(k)$  corresponding to the action of a discrete-time controller and price dynamics determined by  $p$  and the two payoffs. After dispensing with these preliminaries, to make the ideas in this tutorial more concrete, we will discuss a small selection of trading strategies in the literature. This includes trend-following algorithms, methods which are called "model free" such as the Simultaneous Long-Short (SLS) algorithm and the theory of Kelly Betting which originated in the world of gambling. Time permitting, the tutorial will also include a brief introduction to option trading. To gain a basic understanding of how options are used in in practice, rather than getting bogged down with all the mathematics associated with the celebrated Black-Scholes theory, we make use of the good old-fashioned "common sense" and the so-called profit-loss diagram.