Design and Implementation of a High-Frequency Trading System

Daniil Krizhanovskyi

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1 Introduction

High-frequency trading (HFT) has emerged as a dominant force in financial markets, where trading algorithms execute a large number of orders in a matter of milliseconds. This paper provides a detailed architecture of a modern HFT system, focusing on key components such as backtesting, strategy implementation, risk management, logging, and monitoring. Additionally, we will explore the use of contemporary technologies such as Docker, Kubernetes, and Terraform for system deployment and management.

2 System Architecture Overview

An HFT system requires an architecture that optimizes both speed and reliability. Below, we describe the core components and their interaction within the system:

- **Backtesting**: This module allows traders to simulate their strategies on historical data, testing performance and profitability before executing in live markets.
- **Strategy Engine**: This is the heart of the HFT system where various trading strategies are implemented, evaluated, and executed based on market conditions.
- **Risk Management**: This component ensures that trading strategies operate within predefined risk parameters, automatically controlling exposure to prevent significant losses.
- **Logging and Monitoring**: A robust logging mechanism tracks all trades, system activities, and errors, while real-time monitoring ensures that the system is running efficiently and without issues.

3 Key Components

3.1 Backtesting

Backtesting is essential for validating trading strategies. A well-designed backtesting system simulates historical market conditions and analyzes the performance of strategies before deploying them live. It typically involves:

- Historical market data ingestion.
- Simulation of trade executions based on historical prices.
- Reporting of key metrics such as profitability, drawdown, and risk exposure.

3.2 Strategy Engine

The strategy engine is responsible for implementing and executing trading strategies in real-time. The main functions include:

- Processing real-time market data and triggering buy/sell orders based on predefined rules.
- Integration with market exchanges through low-latency APIs.
- Scalability to support multiple strategies operating simultaneously.

3.3 Risk Management

Risk management is critical in mitigating potential losses in high-frequency trading. This module typically performs the following tasks:

- Enforcing position limits and maximum exposure per trade.
- Real-time calculation of key risk metrics, such as Value at Risk (VaR).
- Automatic order throttling or halting in extreme market conditions.

3.4 Logging and Monitoring

Logging and monitoring are vital for maintaining the stability and transparency of the HFT system. A detailed logging system records all trades, system events, and errors. Additionally, monitoring tools help operators track system performance, alerting them to any anomalies or latency issues. The key features include:

- Centralized log storage for efficient querying and analysis.
- Real-time dashboards displaying key system metrics like order execution time and error rates.
- Alerting mechanisms to notify operators of critical failures or market anomalies.

4 Technological Stack

In modern HFT systems, technology choices are crucial for both performance and maintainability. We utilize the following tools to enhance our system's infrastructure:

4.1 Docker

Docker is used for containerizing applications, allowing for isolated environments where components like the strategy engine, backtester, and logging systems can run independently. The benefits include:

- Consistent environments for development, testing, and production.
- Lightweight containers that ensure low overhead.
- Simplified deployment and scaling of individual system components.

4.2 Kubernetes

Kubernetes is employed to manage and orchestrate the Docker containers. It enables the HFT system to scale automatically in response to market conditions and system load. Key features include:

- Automatic scaling of services based on demand.
- Self-healing capabilities, ensuring high availability of the system.
- Efficient resource management and load balancing across the infrastructure.

4.3 Terraform

Terraform is used for infrastructure provisioning and management. With Terraform, we can define the system infrastructure as code, which simplifies deployment and scaling across cloud environments. The primary advantages are:

- Automated infrastructure provisioning across multiple cloud platforms.
- Version-controlled infrastructure, ensuring consistency between environments.
- Simplified scaling of resources based on trading activity or system requirements.

5 Conclusion

The design and implementation of a high-frequency trading system require careful consideration of both software architecture and technology stack. Key components such as backtesting, strategy execution, risk management, logging, and monitoring are essential to ensure the reliability and efficiency of the system. By leveraging modern technologies like Docker, Kubernetes, and Terraform, we can create a scalable, fault-tolerant HFT system that is ready for live trading in dynamic market environments.