

Fast Arbitrage Detection

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Abstract

Triangular arbitrage offers opportunities to exploit price inefficiencies between three currency pairs. While several algorithms exist for arbitrage detection, their computational efficiency and accuracy can vary. In this report, I present a method that combines established graph-based algorithms with **fixed-point** representation techniques to detect triangular arbitrage efficiently and accurately. The approach leverages the **Bellman-Ford algorithm** for cycle detection, enhanced by numerical optimizations to minimize floating-point errors. Experimental results demonstrate that this method improves detection speed and reliability, making it suitable for real-time financial applications.

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1 Introduction

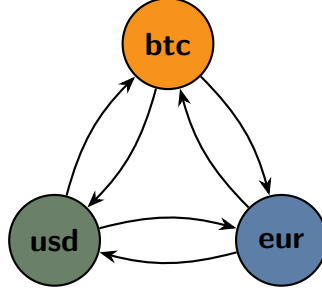
The process to exploit triangular arbitrage opportunities involves 3 generic steps, each crucial for ensuring the success of the strategy:

1. **Data Collection:** Gather real-time exchange rates for the currency pairs involved.
2. **Data Manipulation:** Use the collected data to detect profitable trades.
3. **Execution:** Execute trades to lock in profits.

For all three steps, the **speed** and **accuracy** of the algorithm are paramount. All the efforts become vain if somebody else collects, manipulates, and executes the arbitrage opportunity before you do. On this report, I will focus on the **second step**—*data manipulation*—, which is the most short-lived. The other two steps rely on external factors, such as networks and exchange APIs.

2 Representation

To visualize triangular arbitrage, we can represent it as a **directed graph** (more precisely a clique), where each node represents a currency and each edge represents an exchange rate.



3 Arbitrage Formula

3.1 Base Formula

The formula to detect a profitable triangular arbitrage path, given three exchange rates R , is the following inequality:

$$R_1 \cdot R_2 \cdot R_3 > 1 \quad (1)$$

3.2 Floating-Point Representation

In practice, each price is a floating-point number, and often times, if the *data collection* layer is serious about efficiency, they are provided as **mantissa** (m) and **exponent** (e) separately. So our inequality becomes:

$$(m_1 \cdot 10^{e_1}) \cdot (m_2 \cdot 10^{e_2}) \cdot (m_3 \cdot 10^{e_3}) > 1 \quad (2)$$

$$m_1 \cdot m_2 \cdot m_3 \cdot 10^{e_1+e_2+e_3} > 1 \quad (3)$$

$$m_1 \cdot m_2 \cdot m_3 > \frac{1}{10^{e_1+e_2+e_3}} \quad (4)$$

$$m_1 \cdot m_2 \cdot m_3 > 10^{-(e_1+e_2+e_3)} \quad (5)$$

3.3 Logarithmic Form

In most computer systems, where registers are limited to 64 bits, the product of three mantissas can easily overflow. To address this, we can use logarithmic properties to transform the **product** into an **addition** of much smaller numbers and the **power** into a **product**:

$$\log_b(m_1 \cdot m_2 \cdot m_3) > \log_b(10^{-(e_1+e_2+e_3)}) \quad (6)$$

$$\log_b(m_1) + \log_b(m_2) + \log_b(m_3) > -(e_1 + e_2 + e_3) \cdot \log_b(10) \quad (7)$$

For the sole reason of addressing the overflow issue state above, the choice of the base b can be arbitrary. But in reality things are much more complicated.

- A larger base b will result in a smaller logarithm, which can lead to a loss of precision.
- \log_2 is often faster to compute on most hardware, thanks to bit-shifting operations.
- \log_{10} allows for a simplification of the formula: $\log_{10}(10) = 1$.

- 4 Bellman-Ford Algorithm
- 5 Fixed-Point Representation
- 6 Relative Error
- 7 Optimization