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Currency Arbitrage Detection

Pranit Mahajan, Vinayak Jadhav, Yagnesh Salian
Sardar Patel Institute of Technology
Electronics and Telecommunication Dept.

Abstract:- Arbitrage is defined as near simultaneous purchase and sale of securities or foreign exchange in different markets in order to profit from price discrepancies. Experts believe in the non-existence of arbitrage in an efficient trade market. Arbitrage results in a high profit in a short duration of time without the need of hedging. Detection plays an important role during an arbitrage as an investor who enters the market early, makes the maximum profit. In our experiment, A Bellman-Ford based model is used for detecting the mis-pricing.

Keywords:- *Arbitrage; Bellman-Ford; foreign exchange; hedging.*

I. INTRODUCTION

Arbitrage is the trading strategy which earns a risk-free profit. This profit is earned by using the opportunities in the differences of the entities in a well-defined and clear-cut market or in the various forms of the market. It is the process of earning a profit which is risk-free by considering the various favorable conditions of differences in rate and cost of the same entity regardless the goods are priced alone or in identical combinations. Because of such price inconsistencies and variations, one can earn a harmless and risk-free status in the market and there is a certain reliability and assurance that he may earn more than his risk-free return. The Forex market is the highest and most liquid market in the world. A highly liquid market has insinuates a lower spread, a high volume and turnover.

Traditionally in the Forex market, the Jump-Diffusion factor is largely absent resulting in much tighter bid-ask spreads. Hence, occasional disparities in the bid-ask prices may lead to a fair amount of risk-free profit. In today's market, price discrepancies can last only for milliseconds or even for less time. Hence the High Frequencies Traders (HFTs) are relying on the highly efficient algorithms and the superfast computers to detect such price differences and to find the opportunity of arbitrage in the market.
In this paper we are focusing on the implementation of an algorithm called the Bellman-Ford Algorithm to detect such scenarios.

II. RESEARCH METHODOLOGY

The FOREX, FX or (Foreign Exchange Market) also known as the currency market has multiple distinctive and desirable features which makes it a perfect, sensible and advantageous environment for hedging and speculation processes. FOREX is one of the largest, crystal clear and free flowing market. Because of this in April 2016, the FX market had an estimation of daily trading value equal to 5.1 trillion US Dollars. In contrary to the stock market, the forex market is open and traded continuously. But during different time frames the trading volume can vary considerably. Particularly the forex market spots a huge rise in the trading volume each week on Sunday at 6.00 PM EST during the opening of the Asian market until Friday at 5.00 PM which is the closing time of the American market.

The situation like opening multiple Forex markets like Tokyo, Sydney, London and New York can increase the trading volume rapidly and can be at the greatest. These markets are opened simultaneously leading to the overlapping. During the London and New York overlapping nearly 75 percent of the Forex market activities occur. The dealer set updates in forex market change at higher rates and the sets can be executed rather than being simply indicative or expressive.

These features are contrary to the equity markets where a huge volume trade can result in significant price change and this impact drastically affects the trade. When sellers and dealers talk about the FX market, they aim to profit by anticipating the future flow and direction of the market.

Arbitrage in the FX market is generally characterized in two categories- First is the arbitrage in FX market depends on the utilization of price variation between multiple currency pairs and the another one relies on the variations from the price relationship between the foreign exchange rate, the forward foreign exchange rate and the respective interest rates on which interest parity must hold on. The reason that attracted the large no of marketers and the practitioners from academics towards arbitrage are - large trading volume, variation in the currencies and the markets, the never ending continuous trading activities and the decreasing transaction loss.

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The main insights and contribution to this literature survey are:

- *Propose a computational framework to detect and quantify Arbitrage opportunities.*
- *Provide adequate conditions for detection.*

III. SOLUTION TO THE PROBLEM

We can take advantage of potential mis-pricings in the Forex market by converting the currencies into a graph and using algorithms to traverse it efficiently.

Looking persistently at these live spot rates is a daunting task in itself. Time plays an important role in such occasions as arbitrage lasts for a very short duration of time and only opportune investors earn optimal profits. Therefore, to overcome this challenge, arbitrage detection gives you an update every time a mispricing occurs in the market. Thus, an investor can enter at a superior position and can make optimal profits until the arbitrage exists. Such problems involving time constraints can be effortlessly explicated by computational algorithms and high-performance systems.

When an arbitrage is discovered the informed traders do not trade vehemently but wait for the liquidity traders to start. This results in a lot of time being lost to analyze the extent of the arbitrage leading to the loss of opportunity cost caused due to the informational edge. A solid computational framework is much required to execute such critical trades.

IV. ALGORITHM

The Bellman-Ford Algorithm is an algorithm used to calculate the shortest path between the two nodes of a graph. The Dijkstra algorithm is much more efficient but Bellman-Ford here is preferred as it can even handle negative edge weights.

The algorithm calculates the shortest path in the bottom to top manner. It first calculates the shortest path with the least number of edges involved. After the nth iteration, it calculates the shortest path with n-1 edges involved. The maximum amount of edges involved in a path is |V|-1 which is why the loop gets iterated |V|-1 times. So, if there's no negative weight cycle present, then we've successfully calculated the shortest path with n being the maximum number of edges. Further one more iteration would find the shortest path with n+1 max edges.

The algorithm works on a graph created by the user and calculates the shortest path. Hence, we create a graph of the majorly traded currencies in the forex market.

We constructed a directed graph O (V,E)

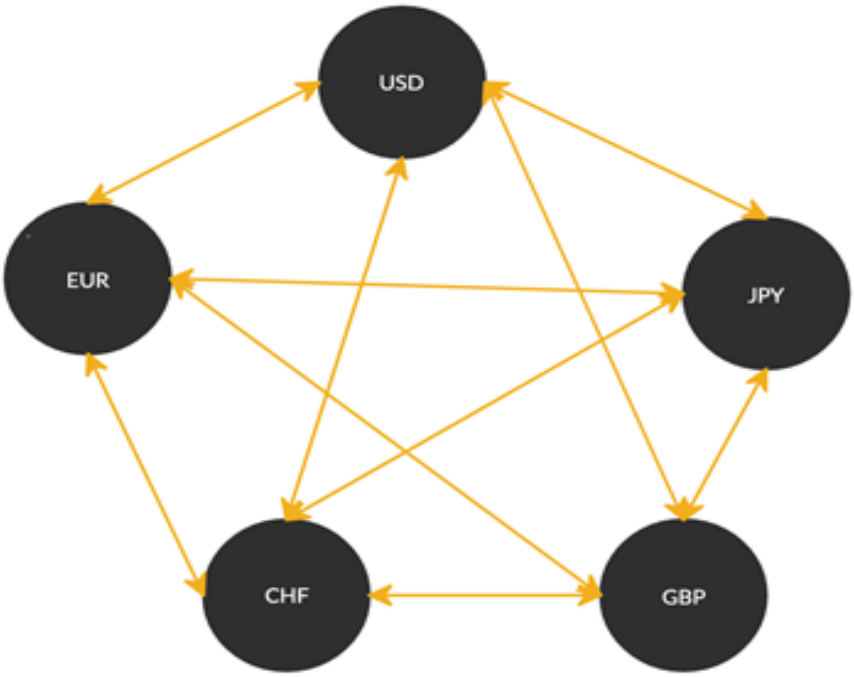

Fig 1

The nodes of the graph represent the Major Currencies in the Forex market while the edges represent the conversion rates. The weight of the edge is the natural log of the respective currency exchange rates.

Hence, we end up with a negative edge weighted graph where the negative cycles determine arbitrage. These negative cycles are detected by Bellman – Ford Shortest Path algorithm with O(V*E) running complexity.

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V. WORKING OF THE CODE

A. Creating the Graph

Creating objects such as nodes and edges with required attributes. The nodes are the primarily used currencies in the Forex namely USD, EUR, GBP, JPY, CHF. The nodes can be extended to take any other exotic currency into consideration.

B. Detecting Cycle

The Bellman-Ford algorithm starts looping through the created array of nodes. We take the negative log of the live exchange rates to form the weights of the edges. If we find a path of nodes such that the sum of their weights is negative, then arbitrage is possible. The Bellman Ford Algorithm helps in detecting negative cycles in O(V*E) time.

When an arbitrage opportunity is found, we print the cycle using the predecessor chain. If we find an edge which can be relaxed further, then we can find the path of the edge. Starting from the source node and traversing backwards, we intend on finding the source node or any other node that the predecessor chain has to print the negative weighted cycle.

When an arbitrage occurs, the function also calculates the profit in pips (Percentage in points).

It is preferable to convert the floating point value to two decimal places and multiply it by 100 and later take the negative logarithm of the value obtained. This is advisable to abstain finding arbitrage opportunities coalescing to less than 1 percent.

C. Conversions and approximations

The logarithm obtained is used to convert the decimal values to integer ones by multiplying them with suitable powers of 10.

VI. RESULTS

The program was successfully able to detect the negative weight cycles, created by us and then consecutively update them. One important feature of the program, the detection of multiple cycles, was also successfully tested. It also calculated the profit in pips on the basis of the spot rates at that very moment.

Considering USD as the base currency.

```
            Live FX Rates
col0  USD     EUR     CHF     GBP     JPY
---- ------ ------ ------ ------ ------
 USD    1.0  0.908 0.9598 0.8099 108.28
 EUR 1.1012    1.0 1.0586  0.892 119.17
 CHF 1.0392 0.9444    1.0 0.8422 112.59
 GBP 1.2335 1.1205 1.1866    1.0 133.67
 JPY 0.0092 0.0083 0.0088 0.0074    1.0

NO ARBITRAGE DETECTED!!!
```

Fig 2

The first test was done on live FX rates imported from Yahoo Finance and the results were as surmised.

```
            Live FX Rates
col0  USD     EUR     CHF     GBP     JPY
---- ------ ------ ------ ------ ------
 USD    1.0  0.908 0.9598 0.8099 108.28
 EUR 1.1012    1.0 1.0586  0.892 119.89
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 GBP 1.2335 1.1205 1.1866    1.0 133.67
 JPY 0.0092 0.0083 0.0088 0.0074    1.0

ARBITRAGE OPPORTUNITY DETECTED!!!
USD --> EUR --> JPY   Profit = 35 pips
```

Fig 3

In the second test, a mispricing was introduced in the EUR-JPY pair. The value of the currency pair was changed from 119.17 to 119.89. The code detected the mispricing and predicted the path of arbitrage and the maximum profit.

VII. FUTURE SCOPE

We would like to work further on this project and make it fully functional for a live Forex environment so that we tackle arbitrage opportunities the moment they come to light.

An arbitrage in the real-world scenario might not be very drastic as the one introduced above. The program was also tested for low pip fluctuations, but it still lacks training on real time data which requires the program to sync with a trading software.

VIII. CONCLUSION

The program worked perfectly on the data provided by manual changes in the pricing as well as the past arbitrage records. It can be used best if run in sync with a trading platform and can detect arbitrage within a millisecond. Such implementations are much needed in this field of work and this project can be further extended to fill the void.

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