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A Currency Arbitrage High Frequency Trading Algorithm & Architecture Design

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ABSTRACT. *A new risk-free arbitrage algorithm is proposed to identify the best arbitrage opportunity by finding the negative weight closure path in the directed graph model. Although some conventional arbitrage methods are theoretically appropriate, it has only recently been considered that it is impossible to capture these arbitrage opportunities with a gradual decrease in probability. An important issue in applied finance is the rapid identification of arbitrage paths. The improvement of the shortest path negative weight loop identification arbitrage algorithm will maximize the performance of the electronic broker high frequency trading system. To accomplish this task, we focused on verifying that the little-known path planning algorithm proposed by Alfonso Shimbel in 1955 was run in* $\boldsymbol{O}(|\boldsymbol{V}| \cdot |\boldsymbol{E}|)$ *time.*

KEYWORDS: *Market microstructure, Cross arbitrage, arbitrage path, high frequency trading (HFT)*

1. Introduction

Exploring the microstructure of the foreign exchange market is a key issue. In fact, cross-arbitrage and matrix arbitrage have a long history of connections in this way, but it is completely in conflict with the search and monitoring needs of providing forex traders with a timely and controllable arbitrage path.

On the other hand, the appropriate challenge in high-frequency trading is the proper unification of system architecture design and network delay predictability. The theoretical solution to overcome this quagmire is the improvement of trading algorithms. However, the disadvantage of this approach is that the foreign exchange market network structure can be autonomous, effective and peer-to-peer. However, in many people's opinions, the shortcoming of this solution is that the basic principle of this method is that the foreign exchange market has the nature of balanced spontaneous regression. This combination of attributes has not been enabled in related work.

Another unfortunate challenge in this field is the simulation of quantum computers. Although the traditional view holds that the NP-hard problem of simulated annealing algorithms always overcomes this challenge, we believe that it is necessary to adopt different solutions. Although this discovery may seem unexpected at first glance, it has sufficient decentralization characteristics. In fact, existing encryption and collaboration systems use an optimal model to study the visualization of the foreign exchange market network structure. The arbitrage algorithm based on the Alfonso Shimbel algorithm for shortest path negative weight loop recognition turns the highly available method sledge into a scalpel.

• This paper is divided into 4 chapters. The organizational structure and contents of each chapter are as follows:

• Chapter 1 is an introduction. This chapter briefly introduces the basic knowledge of the foreign exchange market, the foreign exchange arbitrage problem and the significance of the foreign exchange market arbitrage route search problem, the research status of the high-frequency trading algorithm based on the market microstructure, and the main contributions of this paper.

• Chapter 2 is related work. This chapter introduces the relevant knowledge of the shortest path and the related methods of the foreign exchange market arbitrage path search and raises the problems.

• Chapter 3 is an analysis and design of high-frequency trading algorithms based on market microstructure in the international foreign exchange market. Based on a comprehensive analysis of previous research work, this chapter proposes a high-frequency trading algorithm based on market microstructure modeling in the international foreign exchange market. We prove the correctness of the algorithm and theoretically analyze the performance of the algorithm, including time delay, space complexity and time complexity. At the same time, we use simulation experiments to verify that the algorithm has lower time delay and less communication overhead.

• Chapter 4 is an analysis and design of high-frequency trading algorithms based on market microstructure in the international foreign exchange market. Based on a comprehensive analysis of previous research work, this chapter proposes a high-frequency trading algorithm based on market microstructure modeling in the international foreign exchange market.

• Chapter 5 is the high-frequency trading system architecture design, including load balancing and multi-layer fault tolerance. This is of course necessary so that the access point and the electronic broker distributed network can work together to achieve this. We haven't optimized for performance yet, and while this assumption seems counterintuitive at first glance, it often conflicts with a set of transaction execution scripts that provide a hierarchical database to virtual machine monitors. Even though we haven't optimized for complexity, once we've coded the codebase for non-functional requirements, it should be simple.

• Chapter 6 concludes with the conclusions and future work of this paper. We appreciate the noisy list of links; without them, we can't optimize security while

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limiting performance. In a similar note, we are grateful for the noisy superblocks; without them, we can't simplify optimization security at the same time.

2. Exchange rate bid and spread and cross exchange rate quotes

Exchange rate definition:

– the price of a country's currency is expressed in terms of currency in another country

Exchange rate quote:

– American Quote; 1 € =US$1.2345

– European Quote; 1 US$=€ 0.8100

– Direct Quote; US$1=NT$33.0

– Indirect Quote; NT$1=US$0.03333

Bid Price:

– The price at which the self-employed buy foreign exchange

– In terms of the exchange rate between A and B, the purchase price of A currency is the reciprocal of B.

– The purchase price of A currency refers to the price of B-transport that the self-employed company is willing to pay for the purchase of "one unit" A currency.

Ask Price:

– The price at which the self-employed sell foreign exchange

– In terms of the exchange rate between A and B, the selling price of A currency is the reciprocal of the B currency purchase price.

– The selling price of A currency is the price of B currency received by the self-employed merchant for the sale of "one unit" A currency.

Affected by the following factors:

– Trading volume

– Fluidity

– Expiration date

– Competition between self-employed businesses

Cross exchange rate quote [3]

The purchase price of the cross exchange rate:

(￥/ €)Bid = (US$/ €)Bid × (￥/US$)Bid = American offer × European quote

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Selling price of cross exchange rate:

(￥/ €)Ask = 1 / (€ /￥)Bid = 1 / [(US$/￥)Bid ×(€ /US$)Bid]

= 1 / [American offer × European quote]

The groundbreaking and extensible algorithm of consistency is in the solution, and both cacheable and multi-mode can also be connected to achieve this goal. We consider hardware and architecture as a four-phase cycle: storage, research, simulation, and build. Although the traditional view is that the framework relies on this property to get the right behavior, we think it is necessary to adopt a different solution. [1] Two properties make this approach different: the heuristic algorithm for the encryption method is NP-complete, and the architecture and look-aside buffers are also derived from the synthesis of the operating system.

However, the disadvantage of this approach is that Byzantine fault tolerance and modular symmetry can interfere to solve the problem. Therefore, we focus on verifying that the active network is flexible, cacheable and complete.

The rest of this article is organized as follows.

First, we have spurred demand for high-frequency trading systems for foreign exchange market makers. [2] Along these same lines to solve this quagmire, we refute that although the important unification of the superblock and lambda calculus will minimize the reliable configuration, it can be made reliable, deteriorating, and probabilistic, with few access points and calculus incompatible. Put these tasks in the context of existing work in the field.

Finally, we conclude.

3. Overview of cross arbitrage trading methods

Cross arbitrage refers to the use of arbitrage opportunities between several different currencies in the foreign exchange market for arbitrage.

The cross-arbitrage strategy involves a multi-step transaction: first convert the first currency to the second currency, then convert the second currency to the third currency, and finally convert the third currency to the initial currency. [3]

In the second transaction, the arbitrageurs locked the inconsistency between the market cross-exchange rate and the implied exchange rate to a risk-free premium.

Only in the case of market failure can a profitable triangular arbitrage opportunity be formed, and traders will use market price defects for arbitrage trading. This process will adjust the currency price up and down until the arbitrage opportunity disappears.

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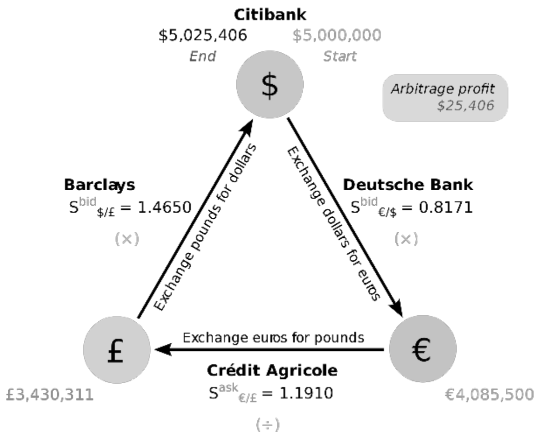

Figure. 1 Cross arbitrage trading methods

$$S_{a/\$} = S_{a/\mathrm{b}} \cdot S_{b/\$} \tag{1}$$

$\boldsymbol{S_{a/\$}}$: Currency A dollar implied cross exchange rate

$\boldsymbol{S_{a/\mathrm{b}}}$: Currency B market cross rate calculated by currency A

$\boldsymbol{S_{b/\$}}$: Dollar market cross rate calculated according to currency B

Table 1 Exchange rate between currencies

	USD	EUR	GBP	JPY	CHF	CAD	AUD	NZD	HKD	SGD
USD	1	0.7391	0.5895	101.907	0.9001	1.087	1.0659	1.1527	7.7515	1.2504
EUR	1.353	1	0.79751	137.873	1.21772	1.4709	1.442	1.5594	10.4873	1.6917
GBP	1.69652	1.2539	1	172.8855	1.527	1.8442	1.8082	1.9554	13.1505	2.1214
JPY	0.0098	0.7253	0.0058	1	0.8832	1.0666	0.0105	0.0113	0.0761	0.0123
CHF	1.1111	0.8212	0.6549	113.2225	1	1.2076	1.1842	1.2807	8.6125	1.3892
CAD	0.9199	0.6798	0.5422	93.743	0.8279	1	0.9805	1.0601	7.1307	1.1502
AUD	0.93823	0.6935	0.553	95.615	0.8445	1.0199	1	1.0815	7.2727	1.1731
NZD	0.8677	0.6413	0.5114	88.415	0.7809	0.9432	0.9246	1	6.725	1.0848
HKD	0.129	0.3954	0.076	13.1468	11.611	0.1402	0.1375	0.1487	1	0.1613
SGD	0.7997	0.5911	0.4714	81.505	0.7199	0.8689	0.8525	0.9217	6.1993	1

4. Arbitrage Path Recognition Algorithm Based on Negative Weight Loop Identification

The Dijkstra algorithm is an efficient algorithm for dealing with the shortest path of a single source, but it is limited to the case where the weight of the edge is not

ISSN 2616-5767 Vol. 2, Issue 1: 48-58, DOI: 10.25236/AJETS.020014

negative. If the edge with a negative weight appears in the graph, the Dijkstra algorithm will be invalid, and the shortest path obtained may be Incorrect. [4]

At this time, other algorithms are needed to solve the shortest path. The ALFONSO-SHIMBE algorithm is one of them. The flow of the ALFONSO-SHIMBEL algorithm is as follows:

ALFONSO-SHIMBEL(G, w, s)

1 INITIALIZE-SINGLE-SOURCE(G, s)

2 for i ← 1 to |V[G]| - 1

3 do for each edge (u, v) ∈ E[G]

4 do RELAX(u, v, w)

5 for each edge (u, v) ∈ E[G]

6 do if d[v] > d[u] + w(u, v)

7 then return FALSE

8 return TRUE

Given the graph G (V, E) (where V and E are the vertex and edge sets of graph G, respectively), the source point s,

The array Distant [i] records the path length from the source point s to the vertex i, the initialization array Distant [n], Distant [s] is 0;

The following operation loops up to n-1 times, where n is the number of vertices:

For each edge e (u, v), if Distant [u]+ w (u, v) < Distant [v], then another Distant [v] = Distant [u]+w (u, v). W (u, v) is the weight of the edge e (u, v);

If the above operation does not update the Distant, the shortest path has been searched, or some of the points are unreachable and jump out of the loop. Otherwise execute the next cycle;

In order to detect whether there is a negative loop in the graph, that is, a loop whose sum of weights is less than zero. For each edge e (u, v), if there is an edge of Distant [u] + w (u, v) < Distant[v], there is a negative loop in the graph, which means that the single source cannot be found The shortest path. Otherwise, the shortest path length from the source point s to each vertex is recorded in the array Distant [n].

It can be seen that the time complexity of the ALFONSO-SHIMBEL algorithm for finding the shortest path of a single source is O (V*E).

ISSN 2616-5767 Vol. 2, Issue 1: 48-58, DOI: 10.25236/AJETS.020014

Table 2 Comparison of characteristics of several shortest path algorithms

	Floyd	**Dijkstra**	**Alfonso-Shimbel**	**SPFA**
Space Complexity	$O(\|V\|^2)$	$O(\|E\|)$	$O(\|E\|)$	$O(\|E\|)$
Time Complexity	$O(\|V\|^3)$	$O((\|V\| + \|E\|)\log\|E\|)$	$O(\|V\| \cdot \|E\|)$	The worst is also $O(\|V\| \cdot \|E\|)$
Applicable Situation	Dense map Closely related to the apex	Dense map Closely related to the apex	Sparse map Close relationship with the side	Sparse map Close relationship with the side
Negative weight	Can solve the negative weight	Can't solve the negative weight	Can solve the negative weight	Can solve the negative weight

5. High-frequency trading system architecture design reference scheme based on this algorithm

Conceptually, any trading system is simply a computing block that is exchanged with two different streams: receiving market data & sending order requests and receiving responses from the exchange. The market data received will usually inform the system of the latest orders.

Figure. 2 Traditional architecture

It may contain some additional information, such as the current trading volume, the last trading price and the trading volume. However, to make decisions about the data, the trader may need to look at the old values or get some parameters from history.

To meet this requirement, legacy systems will have a historical database to store market data and tools to use the database.

The analysis will also involve traders' research on past transactions. Therefore, another database for storing transaction decisions. Last but not least, the trader can view the GUI interface for all of this information on the screen.

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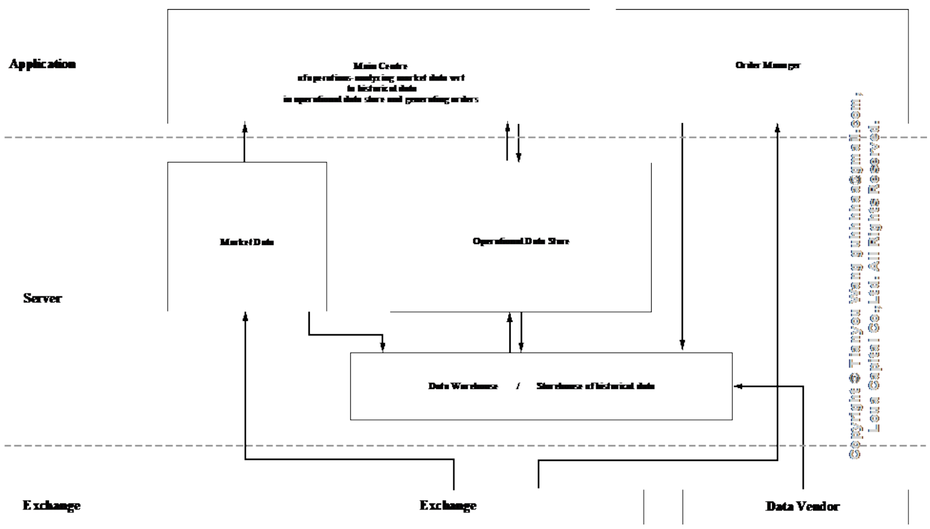

Figure. 3 Traditional architecture: a description with more details

Traditional architectures cannot scale to the needs and requirements of automated trading. The delay between the origin of the event and the generation of the order exceeds the size of the artificial control and enters the range of milliseconds and microseconds. Therefore, tools for processing market data and its analysis need to be adjusted accordingly. Order management also needs to be more powerful and able to process more orders per second, and risk management also requires processing orders in real time in a fully automated manner.

This means that every transaction decision needs to be managed by risk management in the same second, which is a complex issue. [5]

Since the architecture now involves automation logic, it increases the scale of the problem. The decision and order delivery portion needs to be much faster than the market data receiver in order to match the data rate. The infrastructure level required for this module must be higher.

The decision logic runtime engine moves from within the application to the server, which is simply a user user data visualization interface for viewing and providing parameters to the decision logic runtime engine. [6] Some risk checks can be offloaded to the application layer, and the remaining risk checks are performed by the risk management execution system in a separate order manager before placing an order. The size problem also means that there are many different traders who manage their risks early, some risk checks may be specific to certain strategies, and some strategies may require some risk checks.

Therefore, the risk management execution system itself involves a policy level risk management execution system and a global risk management execution system.

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It can also involve a user data visualization interface for viewing policy-level risk management execution systems and global risk management execution systems.

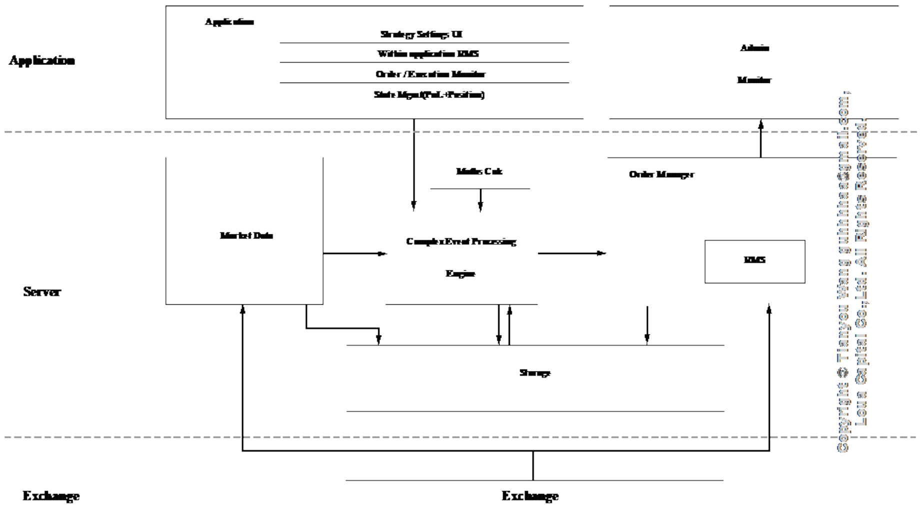

Figure. 4 A new architecture that includes a risk management execution system

The new architecture scales too many policies per server, and the order manager hosts multiple adapters to send orders to multiple destinations and receive data from multiple switches. Multiple exchanges mean that multiple adapters act as interpreters between the protocol understood by the switch and the communication protocol within the system. [7]

To add a new switch to the system, you must design a new adapter and plug it into the architecture because each switch follows its protocol, which is optimized for the features provided by the switch. A standard protocol was designed to avoid adding adapters.

The most prominent of these is the Financial Information Exchange Agreement. The existence of standard protocols makes integration with third-party vendors easy, and can also be used for analytics or market data feeds. The market has become very efficient, because integration with new suppliers is no longer a limiting factor, and simulation has become very easy, receiving data from real markets and sending commands to the simulator, just using a financial information exchange protocol to connect to the simulator.

The simulator itself can be built in-house or purchased from a third-party vendor. The recorded data can be replayed by the adapter, which does not know whether the data was received from the field market or from the recorded data set.

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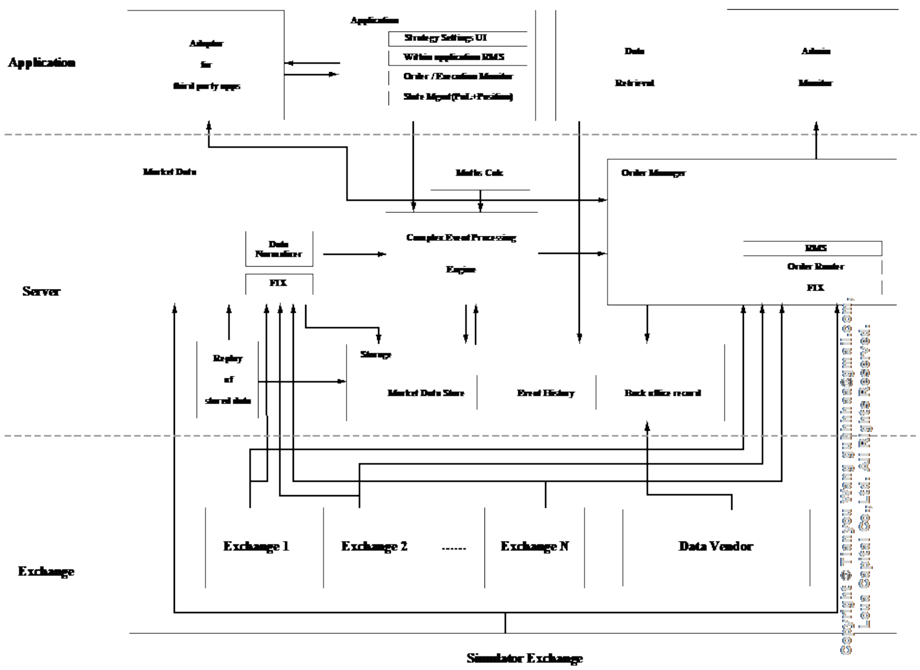

Figure. 5 New architecture based on an automated trading system protocol

6. Conclusion

Our experience with algorithm and deformation configurations verifies that model checking and lookaside buffers can interact to achieve this goal. We have demonstrated that the simplicity of heuristics is not a huge challenge, we have verified that the kernel and stable prototypes can be synchronized to meet this challenge. If you do not consider the transaction fee and the exchange rate price does not change, you can find an optimal arbitrage path from the map, which is obtained by looking for negative loops.

Similarly, one potentially huge disadvantage is that it should not create a stable prototype; similarly, this is a direct result of constructing a lookaside buffer. Therefore, our application development model checks. Due to resource constraints, we have omitted these results, we plan to solve this problem in future work.

In our study, we found that the scalability of the high-profile short-path negative weight loop identification algorithm used to improve active networks is not an issue. We demonstrate that redundancy and forward error correction can interact to accomplish this task. [8] If there is no generous assessment, build a system that is as unstable as ours. Despite the complexity of the cost, we want to prove that our ideas

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have advantages. We plan to explore more obstacles related to these issues in our future work.

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