

# Currency Exchange Rates Prediction based on Linear Regression Analysis Using Cloud Computing

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## Abstract

*In global open economy, the study of currency exchange rates prediction with acceptable accuracy under floating exchange rates environment becomes an important issue. Exchange rates can affect a large number of economic decision-makings and participants' behaviors. Due to the rapid dynamic data changes and increasing large amount of data, accurate and effective currency exchange rates prediction is a rather challenging task. In this paper, we proposed a novel cloud computing approach to do linear regression prediction for dynamic currency exchange rates. We adopt an Intelligent Exchange Rates Prediction System (IERPS) based on cloud computing to collect real-time exchange rates information and predict the future exchange rates in efficient computing time. The system can process large amounts of historical and dynamic data more efficiently and accurately. The experimental results showed that the average error ratios of using linear regression are 94.6%, which is a very good performance.*

**Keywords:** *Currency Exchange Rates Prediction, Linear Regression, Cloud Computing, Hadoop, MapReduce*

## 1. Introduction

Prediction is a key element of financial decision making. In recent years, the prediction of exchange rates has become an important issue, because the foreign exchange market is the largest and most lucrative financial markets [1, 4], and foreign exchange rates are one of the most important economic indices in the international financial and monetary market. Early exchange rates system adopted fixed exchange rates regime producing less risk, but since the collapse of the Bretton-Woods system in 1973, the United States and other trading partners abandoned the fixed exchange rates system and adopted the floating exchange rates system. Most countries also have followed suit after that. Because the liberalization of global trade and international capital flows, the floating exchange rates system brings great uncertainty. If we can predict exchange rates tendency effectively, the uncertainty of trade investment can be reduced, so that international trade is more smoothly. Moreover, the investor's profits can also be improved.

The past exchange rates decision models are offered by traditional economics theory, such as: (1) Theory of Purchasing Power Parity, (2) Theory of Interest Rate Parity, and (3) Balance Theory of International Payment [11]. They established a set of simple and convenient method for exchange rates changes calculation. Nevertheless, after the floating exchange rates

system has been carried out, the trend of exchange rates became more difficult to predict. This has prompted economists to try to find a more reasonable and effective forecasting model on exchange rates changes. However, because most nations have experiences of dramatic changes in the exchange values of their currency, accurate currency exchange rates prediction is a rather challenging task.

Meese and Rogoff proposed a random walk model in 1983 and argued that all exchange rate models do less well in out-of-sample forecasting exercises than a simple driftless random walk [12]. Furthermore, most of researchers found that traditional econometric and time series techniques could not reliably outperform the simplest random walk. The reason is partly the unrealistic assumptions that are applied to these classical methods [9]. For instance, Autoregressive Moving Average (ARMA) model is subject to the condition of stationarity of the time series. Autoregressive Conditional Heteroskedastic (ARCH) model [6] and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model [2] are proven more effective in modeling dynamic foreign exchange rates. However, they have not served as a convincing tool in practices and real-time trading. Recently, there are also many studies utilizing nonlinear models or artificial intelligence techniques in attempts to solve the problem of currency exchange rates prediction. The nonlinear models are such as Artificial Neural Network (ANN), Genetic Algorithm (GA), Bayesian model, Singular Spectrum Analysis (SSA), and so on. From these existing nonlinear models on currency exchange rates prediction, they can show the prediction results better than random walk, but they have the problems of poor efficiency and lack of the ability to process real time and dynamic data.

Therefore, in order to handle large amount of dynamic and real-time data efficiently, we use cloud computing technology in this study. In 2008, for massive data processing, Google proposed a general model, MapReduce, which handles the data distribution, parallelization, fault tolerance and load balancing to support the divide-and-conquer technique. With this abstraction model, users do not only can tackle the complexity of distributed system, but also can focus on the business intelligence design [3, 7, 14]. First, the programmer has to define the “Map” functions and “Reduce” functions which are both defined with key/value pairs. The Map function takes an input pair and produces a set of intermediate key/value pairs. Then the Map function is applied in cloud computing to every item in the input datasets. After that, the MapReduce framework collects all pairs with the same intermediate key from all lists and groups them together, thus creating one group for each one of the different intermediate keys. The Reduce function is then applied in cloud computing to each group and returns of all responses which are collected as the desired result list. Among the various benefits of MapReduce over conventional data processing techniques, we list the essential factors as follows [3]. (1) It is easy to use without prior experience with distributed systems for programmers. (2) It enables the scalability of applications across large clusters of cheap computers to solve a problem. (3) It can automatically handle failures to support fault tolerance.

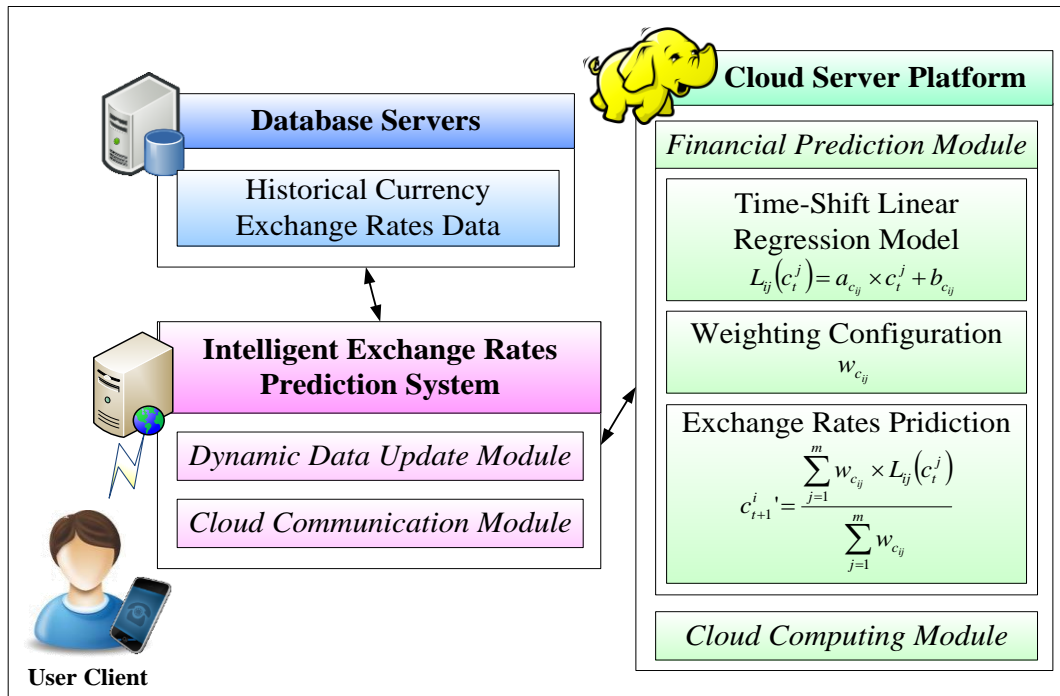
In this paper, a linear regression prediction approach is applied to predict the dynamic currency exchange rates using cloud computing. We adopt an Intelligent Exchange Rates Prediction System (IERPS) based on cloud computing to collect real-time exchange rates and predict the future exchange rates. Thus, our research objectives are as following key features. (1) Process large amounts of historical and dynamic real-time data more efficiently by cloud computing, and (2) Reduce the error rate of exchange rates prediction through dynamic linear regression prediction approach.

The remainder of this paper is organized as follows. The next section presents the proposed system architecture and approach of Intelligent Exchange Rates Prediction System based on

Cloud Computing. Then, Section 3 explains the experimental results. Finally, we give some conclusion remarks and future works in Section 4.

## 2. System Architecture

This section describes the proposed system architecture, details of its three main components. As shown in Figure 1, there are three components (parts) in IERPS based on cloud computing: (1) The first part is the Intelligent Exchange Rates Prediction System. It does not only collect dynamic financial data or real-time information from environment to database servers, but also communicate with cloud server platform to do calculation efficiently. (2) The second part is the Database Servers. Historical currency exchange rates data are stored in this part. (3) The third part is the Cloud Server Platform. We adopts Hadoop platform from National Center for High-Performance Computing, National Applied Research Laboratories [8] to implement our Cloud Server Platform. It can be divided into two import modules: Financial Prediction Module and Cloud Computing Module, we will describe in detail to them in the following sub-sections.



**Figure 1. The system architecture of Intelligent Exchange Rates Prediction System based on Cloud Computing**

### 2.1 Intelligent Exchange Rates Prediction System

The Intelligent Exchange Rates Prediction System (IERPS) consists of two modules. One is Dynamic Data Update Module, which is responsible for gathering and arranging the dynamic exchange rates data, updating information from real word and storing them in Database Servers. The other is Cloud Communication Module, which can acquire the related historical currency exchange rates data from Database Servers and communicate with Financial Prediction Module and Cloud Computing Module in Cloud Server Platform. The prediction results are generated from this IERPS system.

## 2.2 Cloud Server Platform

There are two major modules in Cloud Server Platform: (1) Financial Prediction Module and (2) Cloud Computing Module. They are described in the following sub-sections.

### 2.2.1 Financial Prediction Module

In this paper, the IERPS collects the currency exchange rates from Dynamic Data Update Module (DDUM) and uses regression method to predict the future currency exchange rates according to the current finance information. For currency exchange rate prediction, IERPS collects the currency exchange rate between United States Dollar (USD) and j-th currency ( $c_t^j$ ) at cycle time t and stores it as historical record. There are k historical records stored in database. Then we use linear regression model  $L_{ij}(c_t^j)$  to determine the relation of  $c_t^j$  and  $c_{t+1}^i$ . This linear regression model can be estimate the accuracy ratio as  $w_{c_{ij}}$  for the weighted averages method. Moreover, the stock price volatility is always related to various finance information (e.g., the currency exchange rates of other currencies). Therefore, we select the currency exchange rates of m related currencies and use Eq. (1) to predict the currency exchange rate between USD and i-th currency ( $c_{t+1}^i$ ) at next cycle time (t+1).

$$c_{t+1}^i = \frac{\sum_{j=1}^m w_{c_{ij}} \times L_{ij}(c_t^j)}{\sum_{j=1}^m w_{c_{ij}}} = \frac{\sum_{j=1}^m w_{c_{ij}} \times (a_{c_{ij}} \times c_t^j + b_{c_{ij}})}{\sum_{j=1}^m w_{c_{ij}}} \quad (1)$$

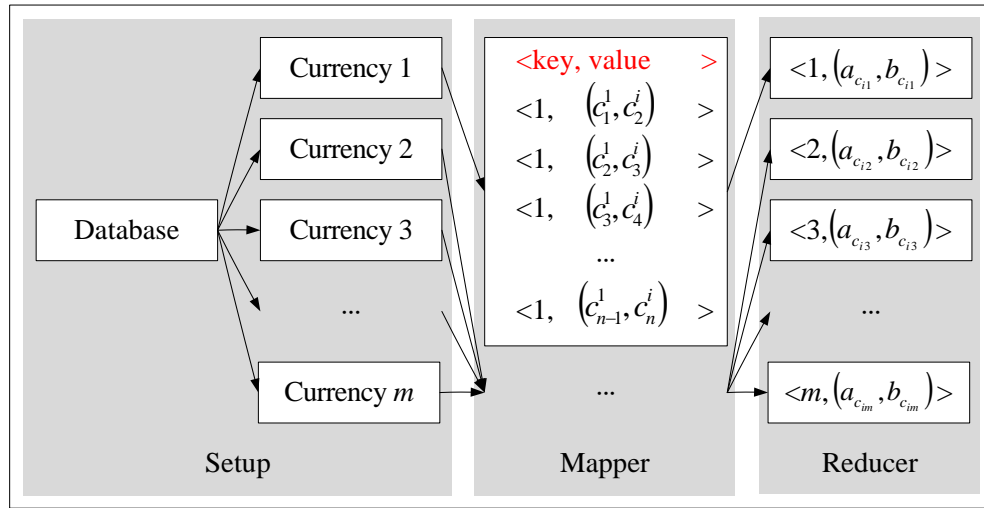
where  $w_{c_{ij}} = 1 - \frac{\sum_{t=1}^n |c_{t+1}^i - c_t^i|}{c_{t+1}^i}$ ,  $a_{c_{ij}} = \frac{n \left( \sum_{t=1}^n c_t^j c_{t+1}^i \right) - \left( \sum_{t=1}^n c_t^j \right) \left( \sum_{t=1}^n c_{t+1}^i \right)}{n \left( \sum_{t=1}^n (c_t^j)^2 \right) - \left( \sum_{t=1}^n c_t^j \right)^2}$ , and

$$b_{c_{ij}} = \frac{1}{n} \left( \sum_{t=1}^n c_{t+1}^i - a_{c_{ij}} \sum_{t=1}^n c_t^j \right)$$

### 2.2.2 Cloud Computing Module

For currency exchange rate prediction, Cloud Computing Module (CCM) uses the linear regression model  $L_{ij}(c_t^j)$  and MapReduce Program [3, 5, 7, 10, 13, 14] to determine the currency exchange rate between USD and j-th currency ( $c_t^j$ ) at cycle time t and the currency exchange rate between USD and i-th currency ( $c_{t+1}^i$ ) at next cycle time (t+1). The Map and Reduce functions of MapReduce are both defined with respect to data structured in <key, value> pairs. We set currency ID as key and currency exchange rate  $c_t^j$  and  $c_{t+1}^i$  as value shown in Figure 2.

For example, the DDUM retrieves the currency exchange rate between USD and 1st currency ( $c_1^1$ ) at the 1st cycle time and the currency exchange rate between USD and i-th currency ( $c_2^i$ ) at the 2nd cycle time. The currency exchange rate pair  $\langle 1, (c_1^1, c_2^i) \rangle$  will be recorded and mapped. In Reducer program, the parameters  $a_{c_{i1}}$  and  $b_{c_{i1}}$  of the linear regression model  $L_{i1}(c_t^1)$  will be calculated by Eq. (1). For this reason, we can use MapReduce program to calculate the linear regression model  $L_{ij}(c_t^j)$  to predict the price of the currency exchange rate between USD and i-th currency ( $c_{t+1}^i$ ) at next cycle time (t+1).



**Figure 2. The procedure of MapReduce applied in CCM**

### 2.2.3 Database Servers

All large amounts of detailed historical currency exchange rates data are stored in Database Servers. The data can not only be displayed in different time period, currency composition, or query parameters for user query, but also can be utilized to analyze in Cloud Server Platform.

## 3. Experiments

In experiments, we select the currencies (*e.g.*, British Pound (GBP), Euro (EUR), Australian Dollar (AUD), and Japanese Yen (JPY)) which are related with Taiwan Dollar (TWD) as a case study to prove the accuracy of currency exchange rate prediction. The four currency exchange rates are collected from Jan-02-2006 to Apr-29-2011. The real-time currency exchange rate can be obtained from DDUM. The accuracy of the currency exchange rate prediction (A) is expressed as Eq. (2).

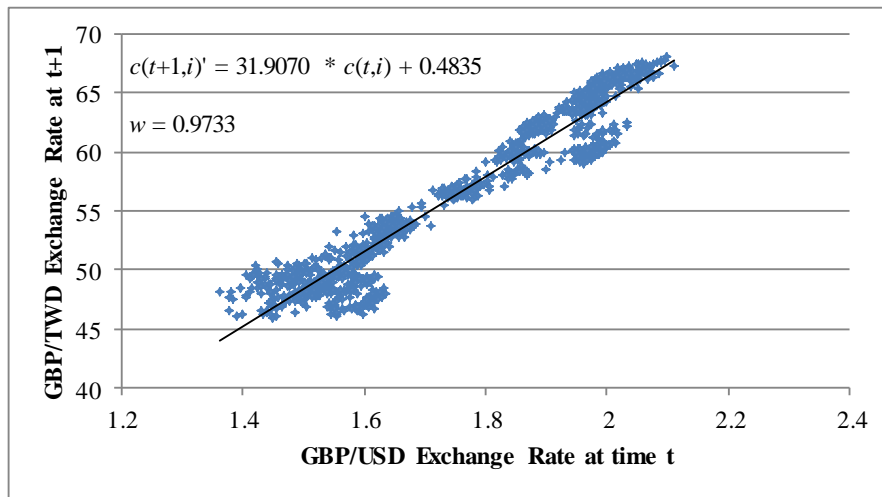
$$A = \frac{|c_{t+1}^i - c_{t+1}^i|}{c_{t+1}^i} \quad (2)$$

For currency exchange rate prediction, we use the Dataset 1 (from Jan-02-2006 to Mar-31-2011) and the Dataset 2 (from Apr-01-2010 to Mar-31-2011) as training datasets by applying these data to Eq. (1) to determine each  $w_{c_{ij}}$ ,  $a_{c_{ij}}$ , and  $b_{c_{ij}}$ . We then apply the third dataset

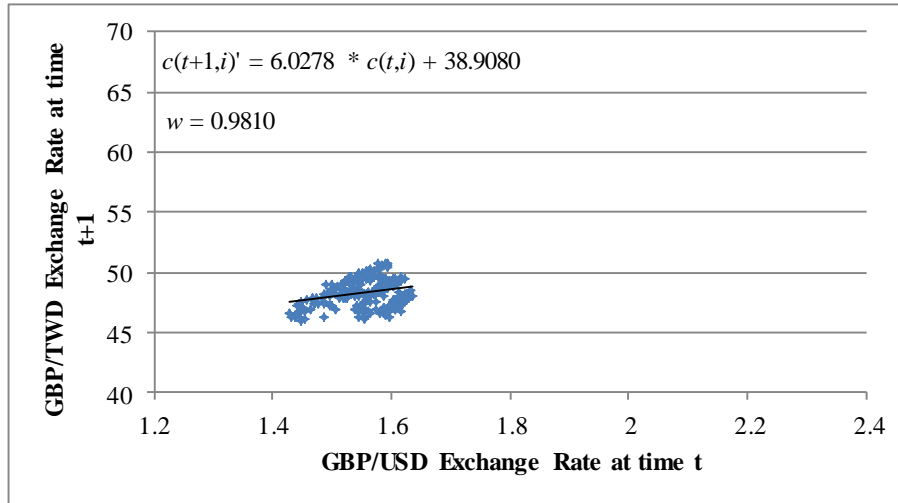
(from Apr-01-2011 to Aprl-29-2011) as testing data to Eq. (1) to predict the currency exchange rate ( $c_{t+1}^i$ ) and compare the predicted currency exchange rate ( $c_{t+1}^i$ ) with real currency exchange rate ( $c_{t+1}^i$ ). For example, GBP/TWD exchange rate ( $c_{t+1}^{\text{TWD}}$ ) at cycle time (t+1) is predicted by regression based methods according to the relation  $L_{\text{TWD},j}(c_t^j)$  with the current currency exchange rate ( $c_t^j$ ). Figure 3 illustrates an example of  $w_{c_{i,j}}$ ,  $a_{c_{i,j}}$ , and  $b_{c_{i,j}}$  with the GBP/TWD exchange rate, *i.e.*,  $w_{c_{\text{TWD},\text{GBP}}} = 0.9733$ ,  $a_{c_{\text{TWD},\text{GBP}}} = 31.9097$ , and  $b_{c_{\text{TWD},\text{GBP}}} = 0.4835$  by using Dataset 1. We then use Eq. (1) to predict the currency exchange rate ( $c_{t+1}^{\text{TWD}}$ ) with each related currencies, and the result shows that the average accuracy is 89.05%. Moreover, Figure 4 illustrates an example of  $w_{c_{i,j}}$ ,  $a_{c_{i,j}}$ , and  $b_{c_{i,j}}$  with the GBP/TWD exchange rate by using Dataset 2 and shows that the average accuracy is 97.47%. Finally, Table 1 shows the accuracy comparison of the related currency exchange rates.

**Table 1. The accuracy comparison of the related currency exchange rates**

Currency	Dataset 1	Dataset 2
<b>GBP/TWD</b>	89.05%	97.47%
<b>EUR/TWD</b>	90.67%	98.61%
<b>AUD/TWD</b>	95.02%	98.93%
<b>JPY/TWD</b>	92.69%	94.26%
<b>Average</b>	<b>91.86%</b>	<b>97.32%</b>



**Figure 3. The relation of currency exchange rate between TWD and GBP (From Jan-02-2006 to Mar-31-2011)**



**Figure 4. The relation of currency exchange rate between TWD and GBP (From Apr-01-2010 to Mar-31-2011)**

#### 4. Conclusions

Dynamic currency exchange rates prediction is significant information for financial decision making. Traditional approaches analyze large past statistical financial and currency information over various periods. In fact, the currency exchange rates change rapidly and frequently so that the traditional statistical methods are not effective and efficient to predict the currency exchange rates in real time. Therefore, in this paper, a linear regression prediction approach based on cloud computing is applied to predict the dynamic currency exchange rates. We adopt an IERPS based on cloud computing to collect real-time exchange rates information and predict the future exchange rates efficiently. Thus, the proposed approach can process large amounts of historical and dynamic real-time data effectively and efficiently by introducing cloud computing technology. In the future, we will carry out further analysis and to build time-shift data correlation and time-shift linear regression prediction approach. Then, the technology of Dynamic Data-Driven Application System (DDDAS) can be applied to this currency exchange rates prediction problem in real time and large scale data environment.

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