Prediction of Host Load in Cloud Computing Based on Quantum Evolutionary Algorithm and Kalman Filter with ANFIS

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Summary
The main target of this paper is to forecast the cloud computing load in the google trace, it presents the use of Kalman filter with a Neuro-fuzzy system composed of an Adaptive Neuro-Fuzzy Inference System (ANFIS) optimized by Quantum Differential Evolution Algorithm. The algorithm was evaluated with actual google cluster trace data and proved the weakness of the comparative method by showing much improved and better predictions by finding the best value for optimization variable in ANFIS using a quantum differential evolution algorithm after applying kalman filter.

Key words:
Cloud Computing, Fuzzy logic, Neural Network, Kalman Filter, Neuro-Fuzzy, Quantum Differential Evolution Algorithm

1. Introduction

Cloud computing is a kind of internet based computing also known as on demand in which the services of computing like storage. Processing elements, resources can be provided according to the user needs. Many people have the different opinion related to the cloud computing.
The main cloud computing is the combination of the cluster and grid computing. The whole internet is work as a cloud in which the Google, Microsoft, Amazon etc. has its own cloud on the internet. [1].
Large-scale cloud computing agencies needs to expend hundreds of millions of electricity to preserve the operation of the physical machines, Cloud computing load forecasting technologies can analyze the previous load and according to these data predict the next stage load, the predicted data can be used to regulate the physical machines so as to minimize the waiting time of the task and realize the purpose of saving energy. Therefore the load forecasting technology has been widespread concerned and researched by scholars in recent years along with resource allocation and virtual machine migration. [2]
Kalman filtering is an algorithm that employ a series of measurements spotted over time, including statistical noise and other inexactness, and generates estimates of unknown variables that tend to be more accurate than those based on a single measurement alone, by using Bayesian inference and estimating a joint probability distribution over the variables for each timeframe. The filter is named after Rudolf E. Kalman, one of the primary developers of its theory. [3]
Kalman filter can generate relatively delicate estimates of unknown variables, using the recursive one-step process on the current estimates and the validated errors of the previous estimates. However, such an approach is infeasible in our situation in that the validation of the previous estimates always suffers significant lag compared to the current time point. [4]
When either the system state dynamics or the observation dynamics is nonlinear, the conditional probability intensity functions that spread the minimum mean square estimate are no longer Gaussian. The optimal non-linear filter deploy these non-Gaussian functions and evaluate their mean, which perform a high computational burden. A non-optimal way to solve the problem, in the frame of linear filters, is the Extended Kalman filter (EKF). The EKF implements a Kalman filter for a system dynamics that results from the linearization of the original non-linear filter dynamics around the previous state estimates. [5]
Ideal usage of the Kalman filter comprise smoothing noisy data and giving estimates of parameters of interest. Applications comprise global positioning system receivers, phase locked loops in radio equipment, smoothing the output from laptop track pads, and many more Neural networks and fuzzy logic are complementary tools in building intelligent systems. While neural networks are low-level computational structures that perform well when dealing with raw data, fuzzy logic deals with logic at a higher level, using linguistic information which is given from system analyst. However, fuzzy systems don't have the ability to learn and cannot adjust themselves to a new environment. On the other hand, although neural networks can learn, they are unclear to the user. [6]
A neuro-fuzzy system is a neural network which works like a fuzzy inference model. It can be trained to develop IF-THEN fuzzy rules and determine membership functions for input and output variables of the system. Expert knowledge can be added to the structure of the neuro-fuzzy system. [7]
Differential evolution mutates the element from a population with the difference between randomly-chosen population elements, and then the crossover is done on the

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resulted vector to improve objective function value. The different strategies of DE algorithms have been presented and they can be specified with DE/b/a/c naming scheme. Where "c" identifies the mutated element, "a" is the number of difference elements and "b" denotes the crossover styles, either binomial or exponential. [8]

The proposed model in this research improves the prediction accuracy by applying the Double Chains Quantum Differential Evolution algorithm (DCQDE), using QDE to optimize the value of one from the neuro-fuzzy parameter in ANFIS Model.

According to the concept above, this paper introduces a method to predict the task load situation in google cluster trace. An adaptive network was used in this paper to optimize the fuzzy inference system parameters to overcome constraints of statistical methods after applying kalman filter to the original data. Finally, the proposed model enhance prediction accuracy using QDE in the optimization process for neuro-fuzzy system parameter. The evaluation results showed that building a considerate optimization model lets the performance of the proposed model is better than the comparable model.

This paper is ordered as follows: Section 2 describes the Scientific background and related work discussion. Section 3 defines the proposed model. Section 4 demonstrate the implementation phases. Section 5 explains the evaluation of the proposed model and discuss the final result with other models. Finally the concluding remarks are mentioned in section 6.

2. Background and Related Work

2.1 Cloud Computing

Cloud computing is a computing model that involves outsourcing of computing resources with the power of expendable resource scalability, on-demand supplying with little or no up-front IT infrastructure investment costs. [9]
Cloud computing offers its advantages out of three types of service or delivery models namely infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS) and software-as-a-Service (SaaS). [10]
Governments, research institutes, and industry leaders are running to embrace Cloud Computing to solve their ever growing computing and storage problems arising in the Internet Age. [11]
There are three main factors contributing to the rise and advantages in Cloud Computing:

- Swift reduction in hardware cost and growing in computing power and storage capacity, and the coming of multi-core architecture and modern supercomputers consisting of hundreds of thousands of cores;
- The exponentially rising data size in scientific instrumentation/simulation and Internet publishing and archiving;
- The wide-spread adoption of Services Computing and Web 2.0 applications. [12]

Large-scale cloud computing agencies needs to expend hundreds of millions of electricity to preserve the operation of the physical machines, also needs quite a lot of electrical power to implement physical machine cooling and other peripheral services. It has become the key to enhance the utility in cloud computing by enhance the utilization of the resources. [13]

2.2 Kalman Filter

American scientist R.E. Kalman established Kalman filtering algorithm for discrete random systems based on Wiener filtering, also can be used for linear continuous time systems [14].
General discrete systems can be expressed as in formula [15].

$$X(i+1) = Q(i+1, i)\, X(i) + J(i+1, i)\, s(i) \tag{1}$$

$$R(i+1) = H(i+1)\, X(i+1) + c(i+1) \tag{2}$$

In formula (1) and (2), X (i) is the p-dimensional state vector, R (i) is the v-dimensional observation vector, s(i) is the y-dimensional state vector, c(i+1) is the z-dimensional noise vector measurement. Q(i+1,i) is the state transition matrix from the time i to time i+1, J(i+1,i) is the incentive transfer matrix from time i to time i+1, H (i+1) predictive output matrix for i+1 moments.
The Kalman filter dynamics results from the consecutive cycles of forecasting and filtering. The dynamics of these cycles is obtained and interpreted in the framework of Gaussian probability density functions. Under additional conditions on the system dynamics, the Kalman filter dynamics converges to a steady-state filter and the steady-state gain is derived. The innovation process linked with the filter, that demonstrates the novel information carried to the state estimate by the last system measurement, is introduced. The filter dynamics is interpreted in terms of the error ellipsoids linked with the Gaussian pdf involved in the filter dynamics. [5]

2.3 ANFIS Algorithm

Neural networks and fuzzy logic are two integral techniques in building intelligent systems [16]. While neural networks are a computational structure that perform well when acting with raw data, fuzzy logic handles with logic using linguistic information which is given from system analyst [17]. Fuzzy systems cannot learn and can't

adjust themselves to new climate. On the other hand, although neural networks can learn but they are unclear to the user [6]. A Neuro-fuzzy system is a neural network which acts like a fuzzy inference model.
ANFIS is a class of adaptive networks that are functionally equivalent to fuzzy inference systems. It represents Sugeno & Tsukamoto fuzzy models and uses a hybrid learning algorithm.

2.4 Quantum Differential Evolutionary

2.4.1 Differential Evolution:

Differential Evolution (DE) algorithm is a process that optimizes a problem to minify an objective function which can achieve the objectives of the problem without any change in the bonds.
The DE algorithm is like genetic algorithms, a population based algorithm using the similar operators; mutation, crossover and selection. The main distinction in finding better solutions is that genetic algorithms rely on crossover while DE depend on mutation operation. This procedure is based on the differences between couple of solutions in the population that was chosen randomly. [19]
It has three main feature: find the best global minimum with regardless about the initial generated values, fast convergence and use a few control elements. [20]
The other important benefits are simplicity, speed, easy usage, very readily adjustable for discrete and integer optimization, more efficient in nonlinear constrained optimization and useful in optimize intermodal search spaces. [21]
The algorithm uses mutation operator as a search mechanism and selection operator to boost the search toward the potential areas in the solution space. [8]
The DE algorithm use an irregular crossover which can select child takes attributes from one parent often than it does for others, by using the components of the existing population members to build trial population, the recombination (crossover) operator expeditiously tousle information about successful combinations, pushing the search for a better solution space. [22]

2.4.2 Quantum Differential Evolution Algorithm:

QDEA uses superposition of many states known as Q-bit for the representation of individuals and updates the individuals relying on their values with respect to the global best solution by appropriately control the mutation and crossover parameters and the operators acting directly on the superposition states of the individual. [21]

- Qbit Encode: [23]

Qubit also named quantum bit and it is the minimum information unit in quantum computing, it represents a two - state quantum system.
Compared with classical-bit, the state of quantum-bit can be any linear superposition state between "0" and "1" state, named:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \quad (3)$$

Also normalization condition must be satisfied such that

$$|\alpha|^2 + |\beta|^2 = 1 \quad (4)$$

After we perform a measurement the system is in one of the two basis states:

$|\alpha|^2 \Rightarrow$ *The probability of observing the outcome* 0

$|\beta|^2 \Rightarrow$ *The probability of observing the outcome* 1

3. Proposed Model

Proposed model used to improves the prediction accuracy by applying the double chains quantum differential evolution algorithm (DCQDE), using QDE to optimize the value of one from the neuro-fuzzy parameter in ANFIS Model in Matlab.
According to the concept above, this paper introduces a method to predict the task load situation in google cluster trace. An adaptive network was used in this paper to optimize the fuzzy inference system parameters to overcome constraints of statistical methods after applying kalman filter to the original data. Finally, the proposed model enhance prediction accuracy using QDE in the optimization process for neuro-fuzzy system parameter.
A double chains quantum differential evolution algorithm (DCQDEA) based on the capacity of probability for quantum bits. In this method, the probability capacities of each qubit are symbolized as two genes, each chromosome holds two gene chains, and each of gene chains acts an optimization solution. The number of genes is determined by the number of optimization parameters. Taking each qubit in the optimal chromosome as the target, individuals are updated by applying crossover operation, and mutation on quantum angle by differential evolution to increase the diversity of population. [21]
Performance evaluation of the proposed model was done using performance measurements. These measurements are widely used to estimate the gap between original output and predicted output produced by the proposed model. The proposed model was evaluated using MAE in the experiment.

$$MAE = (1/N) * \Sigma \text{ abs (error)} \quad (5)$$

The main steps and the conceptual design are illustrated in Algorithm 1

Algorithm 1: Proposed methodology

Step 1: Applying Kalman Filter (Phase one)
Step 2: Generate initial random population
Step 3: Calculate parameter value
Step 4: Initialize Anfis model
Step 5: Perform optimization algorithm using DCQDEA (Phase two)
Step 6: Find best performance and accuracy.
Step 7: Stop

4. Implementation

Two major phases constituting the implementation methodology of the proposed model.

A. Phase one: Data Pre-processing:

Pre-processing is a process that turns the raw inputs and outputs into an understandable or acceptable form before the training process. Often, this is used to reduce the dimensionality of the input data and to optimize the generalization performance.

for the volatility characteristic of the load in cloud computing, the first use Kalman filtering its filtering process, resulting in more accurately reflect the characteristics of cloud computing load curve.

B. Phase Two: Optimization algorithm

The double chain quantum differential evolution algorithm is the algorithm used in the optimization phase.

1) Generate initial angle to make double chains from it

$$P_{t,1}=(\cos(L_{t,1}),\cos(L_{t,2}),\ldots,\cos(L_{t,k})) \quad (6)$$

$$P_{t,2}=(\sin(L_{t,1}),\sin(L_{t,2}),\ldots,\sin(L_{t,k})) \quad (7)$$

Where Lt, k is a random number between 0 and 2π, Pt,1 named cosine solution and Pt,2 named sine solution.

2) Transform to solution space

$$Q_{(t,r)c} = 0.5 * [b_t (1+\alpha_{t,r}) + a_t (1-\alpha_{t,r})] \quad (8)$$

$$Q_{(t,r)s} = 0.5 * [b_t (1+\beta_{t,r}) + a_t (1-\beta_{t,r})] \quad (9)$$

Where t= 1: v, r = 1: k, v the number of qubits and k the population size.

3) Calculate value of objective function which equal to

$$1/(1+MAE) \quad (10)$$

4) Sort the best structure.

5) Mutate quantum angles, mutant L_k

$$mutant\ L_k = L_{z1} + H.(L_{z2} - L_{z3}) \quad (11)$$

Where z1, z2, z3 and k are mutually distinct and H is the mutation control parameter which is random number generated in every generation. [21]

6) Apply crossover operation according to

$$CR\,L_{k,t} = \begin{cases} mutant\ L_{k,t} & if\ rand_k(0,1) \le CR \\ L_{k,t} & if\ rand_k(0,1) > CR \end{cases} \quad (12)$$

Where $CR\ L_{k,t}$ the angle is after crossover operation, $L_{k,t}$ is the original angle before mutation and $CR = 0.5$ is the control parameter which is found to be the best value experimentally. [21]

The procedures mentioned above was used to determine the best value for the optimization parameter using double chain quantum differential evolution algorithm and calculate objective function according to ANFIS model using subtractive clustering to generate initial FIS for ANFIS system.

5. Results and Discussion

Google cluster trace data collected for the evaluation. This data set recorded of Google cloud computing center of the task load situation in nearly a month's time.

To show the performance of the proposed model, testing was done on the Google cluster trace data and compare its result with compared model result in [2], obtained result of the proposed model as shown in Fig. 3.

Fig. 1 illustrate the testing of the proposed model in red marks compared with the original data in blue line and K-Anfis model result in green line.

The compared model [2] presents a comparison of the Adaptive Neural Fuzzy Inference System (ANFIS), ARIMA algorithm to predict the untreated load sequence, and the K-ANFIS algorithm proposed in the paper. It evaluate the methods using The Mean Absolute Error (MAE)

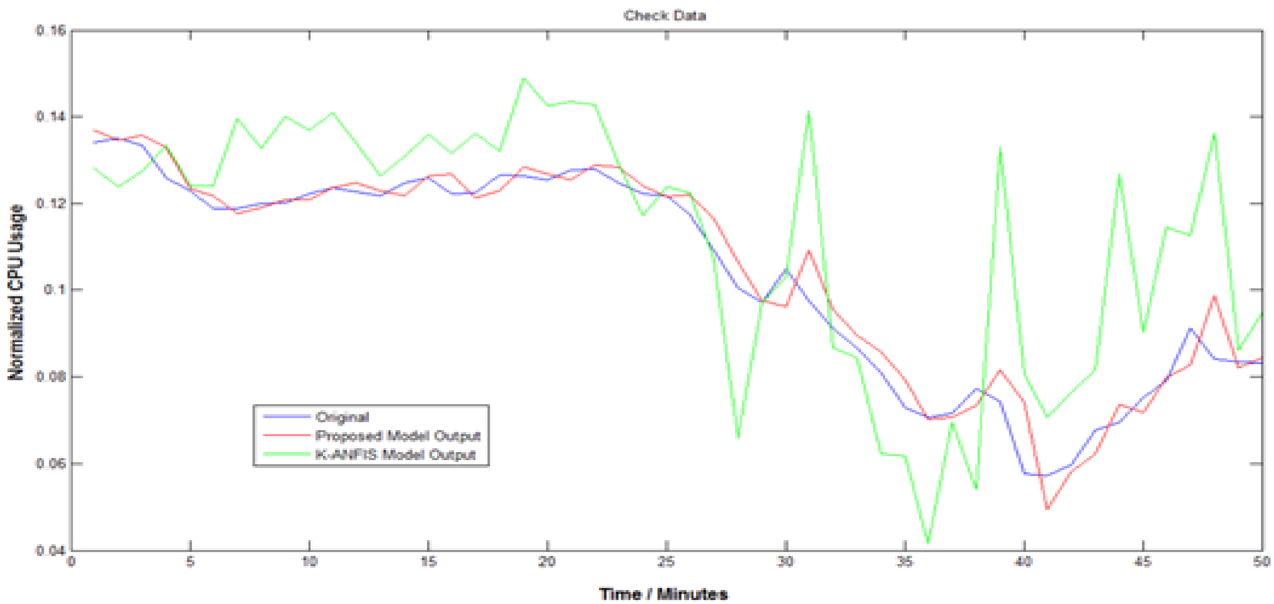

Fig. 1 the Proposed Model Result.

The results in Table (1) show that the proposed model is better than all comparable models.

Table 1: Comparison between the proposed model and comparable models

Model		MAE
Proposed Model		0.0036
Comparable Models	K-ANFIS	0.0291
	ANFIS	0.0343
	ARIMA	0.0375

6. Conclusion

In this study, the main aim of this research is to show the power of QDEA by using it to optimize the parameter used in Neuro-Fuzzy model "ANFIS" to train the system by historical data of google cluster trace data after applying Kalman filter and predict the cloud computing load. The proposed model was implemented and evaluated using Google cluster trace and compared with K-ANFIS and ANFIS models. The obtained result showed the performance of the proposed model is better than the comparable models.

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