Journal of the Nigerian Association of Mathematical Physics
Volume 31, **(July, *2015*), pp 101 – 106**

Credit Card Fraud Detection Using Firefly Algorithm

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Abstract

In this study, a Firefly Algorithm (FA) based Credit Card Fraud Detection (CCFD) for e-payment system is presented. This takes into consideration, discrete optimization problem associated with arbitrary changes in the state of credit card holder's behaviour variables that occur as payment transactions progresses. However, the existing CCFD techniques always lead to false fraud alerts and eventual misclassification of transaction decisions. Genetic Algorithm (GA), a bio-inspired algorithm and other computational intelligence techniques have been used earlier for CCFD. From literature, it has proven that FA is superior to GA because of its efficient global search strength. Hence, FA, a meta-heuristic algorithm is proposed in this study and to the best of our knowledge, FA has never been used in detecting credit card fraud.Meanwhile, FA takes inputs from account details of credit cards andfraud rules setto classify frauds based on Critical Value Identification (CVI) for each credit card. CVI determines light intensity and minimum attractiveness (brightest firefly) used to develop the FA objective function neededto minimize false fraud alert being experienced in CCFD system.

Keywords: Fraud detection system, electronic payment system, credit card, firefly algorithm, critical value identification.

1.0 Introduction

Nowadays, the utilization of electronic payment is daily on the increase worldwide, most especially, in the developing countries; while more countries are moving towards cashless society. Furthermore, it has been discovered by experts over the years that credit cards have become one of the most common forms of payment for e-commerce transactions. However, a major set-back credit card technology is facing is fraud. Generally, fraud is defined as an unauthorized activity taking place in the electronic payments systems. This paper is focused on financial fraud pertaining to credit card transactions. Meanwhile, the use of computational intelligence techniques is on the increase in detecting credit card frauds and the need to handle optimisation issues such as minimizing false fraud alerts and maximizing volume of transactions above the limit in Credit Card Fraud Detection(CCFD)using bio-inspired approach have not been adequately researched. However, Genetic Algorithms (GA), a bio-inspired algorithm have been recently used for CCFD[1].Meanwhile, it was observed that Firefly Algorithm (FA), another bio-inspired algorithm is superior to GA and Particle Swamp Optimisation (PSO)[2].Yang[2] proposed a Firefly Algorithm (FA) at Cambridge University, a novel meta-heuristic that is stimulated by the behaviour of fireflies. Researchers have applied FA in solving mixed variable structural optimization[3]and in tackling cell formation problems [4]. This study, therefore, proposes a credit card fraud detection model using firefly algorithm which has not been used before in this domain. Firefly algorithms are optimisation algorithms aimed at obtaining improved solution as time progresses. It is our belief that FA will minimize the false fraud alerts being experienced in other methods, such as Genetic Algorithms.

The rest of the work illustrates the use of FA in the detection of fraud in credit card transaction. Section 2 discusses related works while section 3 explains how to handle fraud detection in credit cards using firefly algorithm. Section 4 discussed how to implement the work and section 5 is conclusion and directions for further research.

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2.0 Related Works

In order to minimize losses experienced by credit card issuing banks and other financial institutions, efficient fraud detection systems must be put in place. Many modern techniques based on artificial intelligence has been used in detecting various credit card fraudulent transactions. Some of these related-techniques are summarized in Table 1.

Table 1: Related techniques in credit card fraud detection

Author	Title	Methodology	Strengths	Weaknesses
Bently et al.[5]	Fuzzy Darwanian Detection of Credit Card Fraud	Genetic programming, Fuzzy Expert System	Very high accuracy, produces low false alarm	Low processing speed, very expensive
Duman and Ozcelik [6]	Detecting credit card fraud by genetic algorithm and scatter search	Genetic Algorithm	High performance, easily accessible for computer programming language, minimizes wrongly classified number of transactions	Expensive
Pun [7]	Improving Credit card Fraud detection using Meta-Learning Strategy	Support Vector Machine	SVMs have better prediction performance in predicting future data	Poor performance with large data
Sandeep et al.[8]	Problem reduction in Online Payment System Using Hybrid Model	Bayesian learning and Information Fusion	improves Detection rate, Processing speed, reduces false alarm, High accuracy, applicable in e-Commerce	It is highly expensive
Patidar and Sharma[9]	Credit Card Fraud Detection using Neural Network	Bayesian Network and Neural Network	Provides good accuracy, learns well,	Needs high processing time, needs data training
Imouokhome and Jibunoh [10]	Credit card fraud detection using Hidden Markov model and fuzzy logic	Hidden markov model and fuzzy logic	Uncertainty in data are take care of and the framework accommodate purchases above the lomit of the card holders spending profile.	The adoption of fuzzy logic is based on the present knowledge of the behaviour of credit card holder and does not consider changes as the transaction progresses.

3.0 Design Methodology

This section highlights the design procedure for the identification of credit card frauds by applying the Firefly Algorithm (FA).

3.1 Firefly Algorithm

Gao et al.[11] identifies (FA) as a technique used in solving continuous optimization problem. Hence, in order to adapt Firefly Algorithm to the detection of fraud on credit card payment system, there is need to implement these functions such as initial solution , attractiveness and distance (x_i, x_j) between the fireflies, see (Fig. 1) .

The basic steps of Firefly Algorithm are further explained as follows:

(a) Initial Solution: In the basic form of the firefly algorithm, the initial solutions of fireflies are assumed to be uniformly distributed over a particular search space [2]. Meanwhile, there is

(b) need to produce *m* random permutations of (*1, 2…, n*) for the initial fireflies, with $T_n$as the search space..This study proposesa method, called Critical Value Identification (CVI); to obtain the critical value of each fireflywhich represent its light intensitythat defines the brightness of each firefly[11].

(c) Distance Function: The measure of distance between fireflies within the coordinate (x_i , x_j) is computed using Cartesian distance

$$r_{ij} = |(|x_i - x_j|)| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \quad (1)$$

where $x_{i,k}$ is the kth component of the spatial coordinate x_i of the *ith* firefly and d is the number of dimensions[12].

(c) Light Absorption Coefficient: In FA, two vital issues are involved, such as light intensity variation and attractiveness formulation. However, Yang [2]assumed that the attractiveness of firefly is determined by its brightness which in turn is associated with the encoded, objective function[13].

(d) **Attractiveness:** Gao et al.[11]discussed further that eachfirefly movementis proportional to its brightness, thus for any two flashing fireflies, the less bright one will move towards the brighter one. However, attractiveness is proportional to the brightness and they both decrease as their distance increases. If there is no brighter one than the others, it will move randomly. Meanwhile, with observation on the computed critical values of each credit card, we select a brighter one and the attractiveness of the other ones is computed. With the attractiveness proportional to the light intensity (brightness) with respect to distance,a formula is derived.The attractiveness function β of a firefly is determined as

$$\beta = \beta_o e^{-\gamma r^2} \quad (2)$$

r = distance between any two fireflies, βo = initial attractiveness at r = 0, and γ = absorption coefficient which controls the decrease of the light intensity[14].

$$\beta \alpha I, \quad \beta \alpha 1/r \qquad \beta = \gamma * I/r \quad (3)$$

Mathematically, we can represent this as $\beta \alpha \gamma I/r$, that is, attractiveness is the "light intensity multiplied by the light absorption coefficient divided by the distance[14]".

(e) **Movement:** The movement of a firefly i is attracted to another more attractive (brighter) firefly j is determined by:

$$x_i = x_i + \beta_o e^{-\gamma r_{ij}^2}(x_j - x_i) + \propto \left(rand - \frac{1}{2}\right), \quad (4)$$

Where the second term is due to the attraction the third term is randomization with ∝ being the randomization parameter. *rand* is a random number generator uniformly distributed in [0, 1].

In summary, for FA Algorithm in Fig. 1, each firefly generates an initial solution randomly; parameters like light intensity *I*, Initial Attractiveness β, and light absorption coefficient γ are defined. Furthermore, each firefly, then find the brightest firefly[11]. Less bright firefly will move towards the brighter firefly if there is one. When firefly moves, its light intensity decreases and its attractiveness will change. Finally, the best firefly will be chosen based on an objective function for the next iteration. This condition will continue until the maximum iteration is reached[11].

```
Objective function f(x), x = (x1... xd)T

Generate initial population of fireflies xi(i = 1, 2... n)
Light intensity Ii at xi is determined by f(xi)
Define light absorption coefficient γ
while (t <MaxGeneration)
   fori = 1 : n all n fireflies
      for j = 1 : n all n fireflies (inner loop)
         if (Ii<Ij),
            Move firefly i towards j;
         end if
            Vary attractiveness with distance r via exp[−γ r]
            Evaluate new solutions and update light intensity
      end for j
   end for i
   Rank the fireflies and find the current global best g*
end while
Post process results and visualization
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Fig 1: Basic Firefly Algorithm[2]

3.2 Adapting firefly algorithm for fraud detection of credit card payment system

For the purposes of Fraud Detection of credit card, we define the following parameters;

Definition1: A set of credit card C, is an infinite set of credit cards issued to customers

$$CC = \{cc_1, cc_2, \ldots, cc_n\}$$

Definition 2: A set of credit card frequency usage CCFreq is the set of real values. Where CCFreq = Total number card used (CU) / CC Age. The Age of credit card, CCage in months can be calculated using CCage / 30.

$$CCFreq=\{x_1,x_2,\ldots x_n \mid \text{for all } x \in \mathbb{R}\ \}$$

Definition 3: The total number of Card Used, CU is the set of positive integer, which contains the number of times a credit card is used.

$$CU =\{x \mid x \in \mathbb{Z}\}$$

Definition 4: The total number of location LOC (online or physical location) a credit card is used LOC, is the set of positive integer $LOC =\{y \mid y\in \mathbb{Z}\}$

Definition 5: Critical Value Identification :Compute CC fraud detection by using rules sets for each credit card behaviour e'g CCFreq, CCLoc, CCod, CCbb, CCspending

$$CCFreq\text{CC}\in \text{CVI}$$

3.2.1 Modified Firefly Algorithm for credit card fraud detection

Input: CC_Frequency, CC_Location, CC_overdraft, CC_bookbalance, CCspending

Output:*Ordinay_fraud*, *critical_fraud*, monitorable_fraud*// classification of fraud*

Definition(a) fraudulent activities l_i as light intensity

(b)credit card $x_i$as fireflies

1. Select CCfraud∈ CC | where CCfraud is fraudulent credit card from set of CC
2. Compute CCFraud using Rules based on CCFreq, CCLoc, CCod, CCbb, CCspending
3. Setup firefly algorithmObjective function f(x), $x = (x_1, ..., x_d)^T$
4. Generate initial population of credit cardsx_i(i = 1, 2, ..., n)
5. Light intensity $I_i$at $x_i$is determined by $f(x_i)$
6. Define light absorption coefficient γ
7. While (t < MaxGeneration)
8. For i = 1 : n all n credit cards
9. For j = 1 : i all n credit cards
10. If (I_j>I_i), Move credit cardi towards j in d-dimension;
    end if
11. Attractiveness varies with distance rvia exp $[-\gamma r]$
12. Evaluate new solutions and update light intensity
13. End for j
14. End for i
15. Rank the credit card xi and find the most fraudulent
16. End while
17. Results Analysis and visualization

4.0 Discussions

The credit card holder (user) logs into the CCFD system and details are confirmed. Hence, the fraud detection transaction starts by verifying through the data sets in the account details repository (database) and fraud detection rule set/sets are used to verify whether fraud has occurred or not while transaction processes are stored in the log for detection analysis, see (Fig. 2).

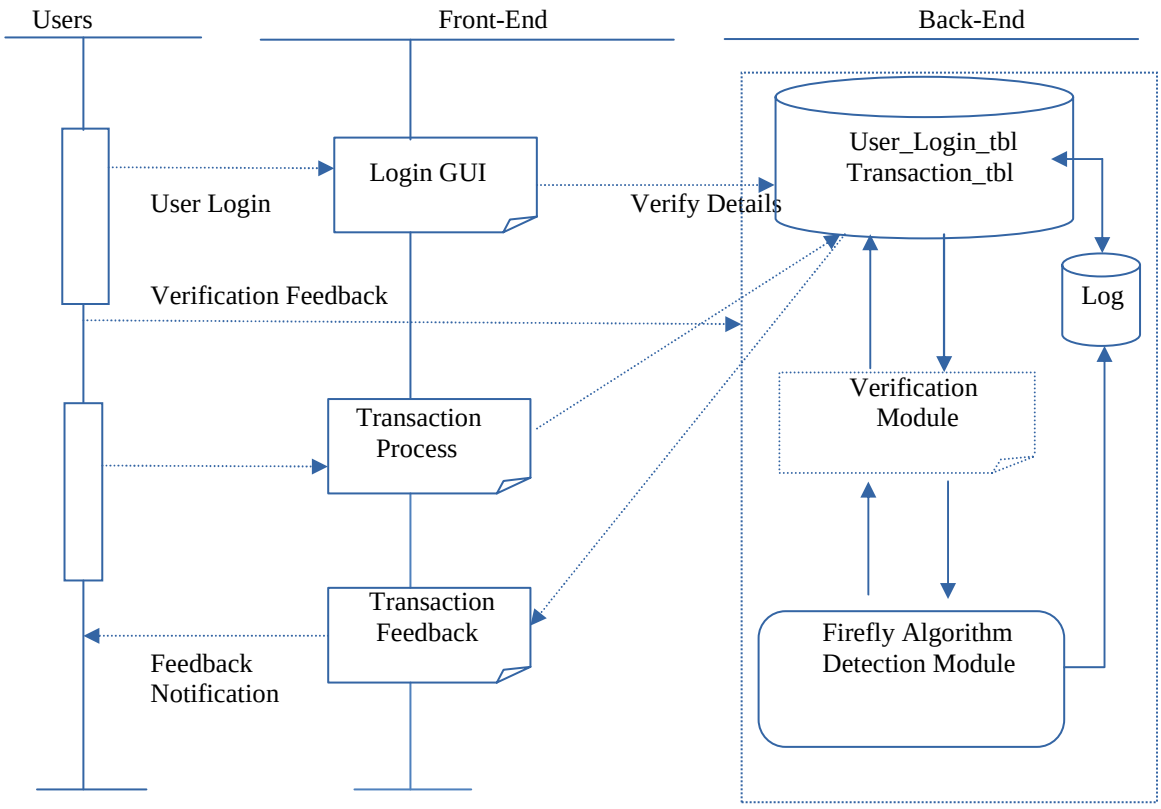

Fig 2: Proposed Model for credit card fraud detection system using Firefly algorithm (adapted from [15])

The test can be carried out basedon the credit card behaviour such as CC usage frequency, CC Usage Location, CC Overdraft,CC BookBalance, and Average Daily Spending[12].Meanwhile, fraudulent cards are detected using critical value identification (CVI) determined by fraud detection rules set foreach credit card behaviour. For each transaction, firefly algorithm is introduced for fraud detection verification while identifying the credit cards with highest possibility of fraudulent traces and identifying the brightest fireflies with highest critical values (light intensity). However, the brightest firefly (credit card) and other less bright (credit cards) are visualized using graphical method with details from credit cards data set (x,y)[card_id, LOC].

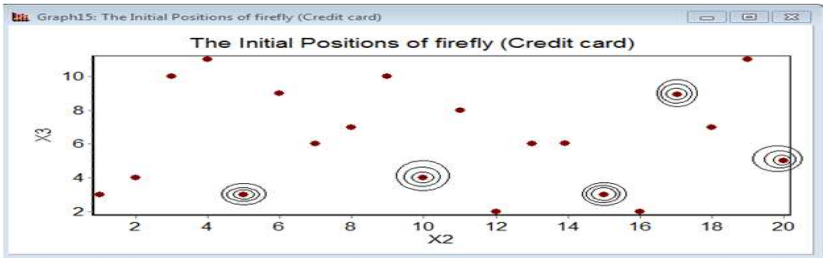

Fig 3: Initial positions of firefly (credit cards)

The graphin Fig. 3 shows the initial position of each credit card (firefly) X3 on the y-axis represent the location with respect to time and X2 on the x-axis represent the credit card identification number. The circled parts are labeled as the critical points of each firefly.

Meanwhile, Cartesian distance is used to measure the distance between the brightest firefly and less bright fireflies (credit cards). Furthermore, firefly attractiveness is computed while noting the objective function of minimizing the false fraud alerts. The objective function enables us to select the firefly that moves towards the brightest firefly on the same fraudulent pattern which needs to be noted. Consequently, after identifying the fraudulent credit cards (fireflies), the number of occurrences (frequencies) and their critical values (light intensity) to identify which of the credit cards can be classified as critical, monitorable and ordinary fraud, stored in security database and reports are generated. The classification rules are based on the policy of the financial organisation.

5.0 Conclusion

This study presented a framework for detecting credit card fraud based on the principles of the Firefly Algorithm(FA). FA is an optimization algorithm which aims at obtaining better and optimal solutions as time progresses. So far, FA which to the best of our knowledge has never been used for credit card frauds detection was introduced. We can, therefore, conclude that, if this algorithm is applied to bank credit card fraud detection systems, these fraudulent transactions can easily be detected and reported immediately after each credit card transaction by the concerned financial institution. Also, a sequence of anti-fraud strategies can be adopted to prevent these institutions from great losses, thereby reducing business risks.

6.0 References

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