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Bacterial Algorithm For Detecting Money Laundering Activities in a Financial System

Khalil Ibrahim Alsaif , Ramadan Mahmood Ramo
Department of Computer - University of Mosul, Management Information systems - University of Mosul

Abstract - Bacteria algorithm is one of the evolutionary algorithms used to search for the optimal solution. This algorithm has been developed to detect money laundering in the financial system of banking operations. The bacteria algorithm is based on four phases that will be explained in detail during the research. Money laundering is the generic term used to describe the process by which criminals disguise the original ownership and control of the proceeds of criminal conduct by making such proceeds appear to have derived from a legitimate source.

***Keyword:* Bacterial Algorithm, clustering. Money laundering.**

I. BACTERIAL FORAGING OPTIMIZATION ALGORITHM (BFOA)

Bacterial Foraging Optimization Algorithm (BFOA) is proposed by Kevin Passino (2002), is a new comer to the family of nature inspired optimization algorithms. Application of group foraging strategy of a swarm of E.coli bacteria in multi-optimal function optimization is the key idea of this new algorithm. Bacteria search for nutrients is a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis. The key idea of BFOA is mimicking chemotactic movement of virtual bacteria in the problem search space. [3]

p: Dimension of the search space,
S: Total number of bacteria in the population,
Nc : The number of chemotactic steps,
Ns : The swimming length.
Nre : The number of reproduction steps,
Ned: The number of elimination-dispersal events,
Ped : Elimination-dispersal probability,
C (i): The size of the step taken in the random direction specified by the tumble.

II. BACTERIAL FORAGING OPTIMIZATION ALGORITHM

Bacterial Foraging optimization theory is explained by following steps:

A. Chemotaxis

Suppose represents the bacterium at j^{th} chemo tactic, kth reproductive, and lth elimination-dispersal step. C(i) is the chemo tactic step size during each run or tumble (i.e., run-length unit). Then in each computational chemo tactic step, the movement of the ith bacterium can be represented

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + C(i)\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$$

Where Δ(i) is the direction vector of the jth chemo tactic step. When the bacterial movement is run, Δ(i) is the same with the last chemo tactic step; otherwise, Δ(i) is a random vector whose elements lie in [−1, 1]. With the activity of run or tumble taken at each step of the chemo taxis process, a step fitness, denoted as J(i, j, k, l), will be evaluated.[7]

B. Swarming

An interesting group behavior has been observed for several motile species of bacteria including E.coli and S. Typhimurium, where intricate and stable spatio-temporal patterns (swarms) are formed in semisolid nutrient medium. A group of E.coli cells arrange themselves in a traveling ring by moving up the nutrient gradient when placed amidst a semisolid matrix with a single nutrient chemo-effecter. The cells when stimulated by a high level of succinate, release an attractant aspertate, which helps them to aggregate into groups and thus move as concentric patterns of swarms with high bacterial density. [6]

C. Reproduction

After chemotactic and swarming periods, some bacteria have enough nutrient and some others are unsuccessful at searching for nutrient. In reproduction part, those bacteria which have enough nutrient will reproduce and others are eliminated. To this end, the health status of each bacterium is calculated as the sum of the step fitness during its life as follows:

$$J^i_{health} = \sum_{j=1}^{N_c} J(i,j,k,l)$$

Values obtained by Jhealth for each individual of the population (bacteria) are sorted in ascending order.. This process not only will keep the population constant, but also the healthier bacteria continue to next generation.[9]

D. Elimination and Dispersal:

Gradual or sudden changes in the local environment where a bacterium population lives may occur due to various reasons e.g. a significant local rise of temperature may kill a group of bacteria that are currently in a region with a high concentration of nutrient gradients. Events can take place in such a fashion that all the bacteria in a region are killed or a group is dispersed into a new location. To simulate this phenomenon in BFOA some bacteria are liquidated at random with a very small probability while he new replacements are randomly initialized over the search space.[1]

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III. WHAT IS MONEY LAUNDERING

Generally, money laundering is Athe process by which one conceals the existence, illegal source, or illegal application of income to make it appear legitimate. In other words, the process used by criminals through which they make a dirty money appear a clean. Though initially considered an aspect integral to only drug trafficking, laundering represents a necessary step in almost every criminal activity that yields profits.

Criminals engage in money laundering for three reasons. First, money represents the lifeblood of the organization that engages in criminal conduct for financial gain because it covers operating expenses, replenishes inventories, purchase the services of corrupt officials to escape detection and further the interests of the illegal enterprise, and pays for an extravagant lifestyle. To spend money in these ways, criminals must make the money they derived illegally appear legitimate. Second, a trail of money from an offense to criminals can become incriminating evidence. Criminals must obscure or hide the source of their wealth or alternatively disguise ownership or control to ensure that illicit proceeds are not used to prosecute them. Third, the proceeds from crime often become the target of investigation and seizure. To shield ill-gotten gains from suspicion and protects them from seizure, criminal must conceal their existence or, alternatively, make them look legitimate. **[10]**

IV. THE MONEY-LAUNDERING CYCLE

Money laundering is generally seen as a three-stage process, as shown in Figure 1.

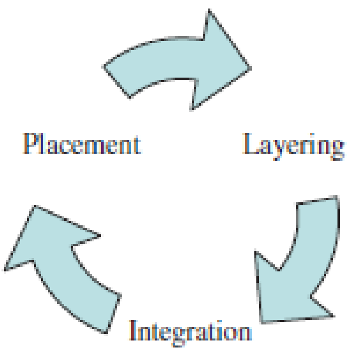

Fig 1: Money Laundering Cycle

A. The Placement Phase

The placement is the initial stage of the process. The illegitimate funds have been obtained in some way, perhaps as a result of extortion, theft or drug trafficking, or any other form of predicate crime. These funds will need to be placed initially into the banking system to commence the money-laundering process. Placement is not just the movement of cash into a bank account, even though this is the process that is most frequently considered. The initial placement purely means moving the funds from their original cash source into some other form which will enable the money launderer to undertake further layering and therefore disguise these amounts. [2]

B. The Layering Phase

Layering is the process of separating the proceeds of criminal activity from their origin through the use of many different techniques to layer the funds. These include using multiple banks and accounts, having professionals act as intermediaries and transacting through corporations and trusts, layers of complex financial transactions, such as converting cash into traveler's checks, money orders, wire transfers, letters of credit, stocks, bonds, or purchasing valuable assets, such as art or jewelry. All these transactions are designed to disguise the audit trail and provide anonymity. [4]

Layering usually involves a complex system of transactions designed to hide the source and ownership of the funds. Once cash has been successfully placed into the financial system, launderers can engage in an infinite number of complex transactions and transfers designed to disguise the audit trail and thus the source of the property and provide anonymity. One of the primary objectives of the layering stage is to confuse any criminal investigation and place as much distance as possible between the source of the ill-gotten gains and their present status and appearance.

Typically, layers are created by moving monies in and out of the offshore bank accounts of bearer share shell companies through electronic funds' transfer (EFT). Given that there are over 500,000 wire transfers – representing in excess of $1 trillion – electronically circling the globe daily, most of which is legitimate, there isn't enough information disclosed on any single wire transfer to know how clean or dirty the money is, therefore providing an excellent way for launderers to move their dirty money. Other forms used by launderers are complex dealings with stock, commodity and futures brokers. Given the sheer volume of daily transactions, and the high degree of anonymity available, the chances of transactions being traced is insignificant [5]

C. The Integration Phase

The third and final phase of the money-laundering process is integration. This is the phase where the layered monies are incorporated into the legitimate financial world and assimilated with the assets of the legitimate system. In other words, it's spending day for the bad guy. This is the light at the end of the tunnel he giant payday for the launderer. Finally, it's what he has been waiting for: the ability to buy cool stuff or do more bad deeds as a result of the proceeds of his crime. He will transfer the funds into the mainstream using various methods such as business investments, big-ticket luxury items, and real estate purchases.

It is the stage at which laundered funds are reintroduced into the legitimate economy, appearing to have originated from a legitimate source. Integration is the final stage of the process, whereby criminally derived property that has been placed and layered is returned (integrated) to the legitimate economic and financial system and is assimilated with all other assets in the system. Integration of the "cleaned"

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money into the economy is accomplished by the launderer making it appear to have been legally earned. By this stage, it is exceedingly difficult to distinguish legal and illegal wealth.

Not all money laundering transactions go through this three-stage process. The three basic stages may occur as separate and distinct phases or may occur simultaneously or, more commonly, they may overlap. Transactions designed to launder funds can for example be effected in one or two stages, depending on the money laundering technique being used. How the basic steps are used depends on the available laundering mechanisms and requirements of the criminal organizations.[8]

V . BACTERIAL FORAGING OPTIMIZATION ALGORITHM

Bacterial Foraging Optimization Algorithm (BFOA) is proposed by Kevin Passino (2002). Application of group foraging strategy of a swarm of Escherichia coli bacteria in multi-optimal function optimization is the key note of this algorithm. This tool helps the user to identify the optimization techniques using the Bacterial Foraging Optimization Algorithm.

- Estimate the fitness value based on the transaction amount,
- Next those fitness value is passed to the BFO algorithm where again BFO fitness is estimated.
- Move the bacterium 1 step forward in the same direction based on the random number.
- Then again calculate the new fitness function.
- By comparing the previous fitness value with new fitness value, if new fitness value is less than the previous fitness value then assign the previous fitness value as new fitness value.
- Worse fitness bacteria is getting died and eliminated that. Best fitness bacteria is getting split and reproduce the new bacteria.
- Reinitialize the bacteria position and finally obtained the best optimum value for detecting money launders.

VI. CONTROL PARAMETERS OF BA

Table (1) represents all the parameters used in the Bacteria algorithm

Table (1): Control Parameters

S.N.	Parameters	Values
1	Number of bacterium, S	12
2	Maximum number of steps, Ns	1
3	Number of chemo tactic steps, Nc	12
4	Number of reproduction steps, Nre	12
5	Number of elimination-dispersal steps, Ned	12
6	Probability, Ped	0.9
7	Size of the step, C(i)	0.01

VII. FLOWCHART

The Figure 2 represents the flowchart to for detecting money Laundering Based to Bacteria Algorithm

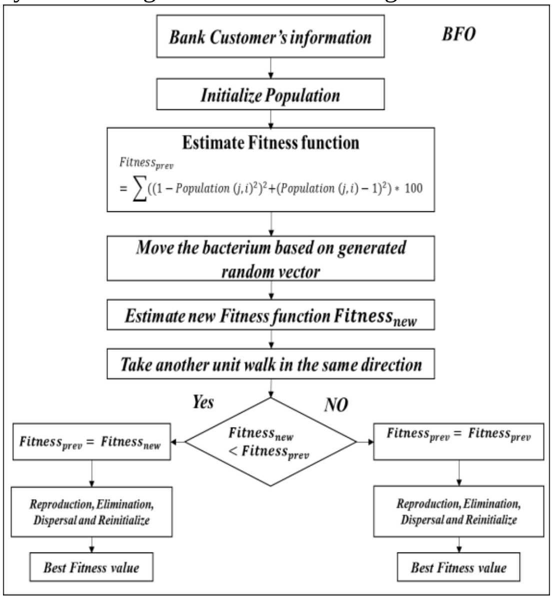

Fig 2: Flowchart of BA

VIII. ALGORITHM OF DETECTING MONEY LAUNDERING BASED ON BACTERIA ALGORITHM

The following steps represent the work mechanism of the bacteria algorithm in detecting money laundering

Input: Clustered Result

Output: Optimized value for Detection

Procedure:

Step 1: Initialize the population, bacteria colony and update chemotactic based on the bacterium,

Population =

where is the sum of the transaction amount of every month

Step 2: Calculate the fitness function of ith bacterium,

For j=1: Nc // Nc - umber of chemotactic steps in a bacterium's life time

For i=1: S // S – bacteria colony size

$$Fitness_{prev} = \sum((1 - Population\ (j,i)^2)^2 + (Population\ (j,i) - 1)^2) * 100$$

End

End

Step 3: Generate random vector which is between the range of [-1, 1], move the bacterium I in the direction based on the random vector.

Step 4: Go to step8 to calculate new fitness

Step 5: Take another unit walk in the same direction,

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If $Fitness_n$

Perform one unit walk in same direction.

$Fitness_p$

End

Step 6: REPRODUCTION: Worst fitness bacteria getting die and best fitness bacteria is getting split and move in same direction.

$Population\ (worst_{fitness}) = empty$

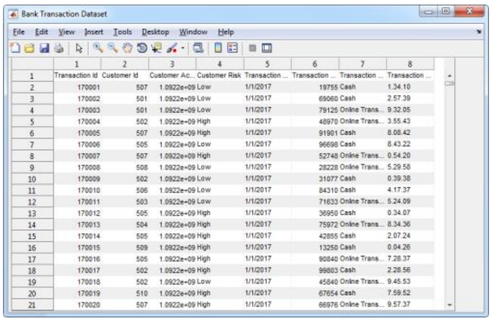
Step 7: ELIMINATION and DISPERSAL: eliminate and disperse each bacterium.

Step 8: REINITIALIZE each bacterium position and finally obtain the best for detection of money launders.

Step 9: Repeat the above steps until reach maximum iteration.

IX. RESULTS

The output of the same (output Collected from the source code of the Appendix) is shown as below, the figure below shows the listing of Initial dataset:

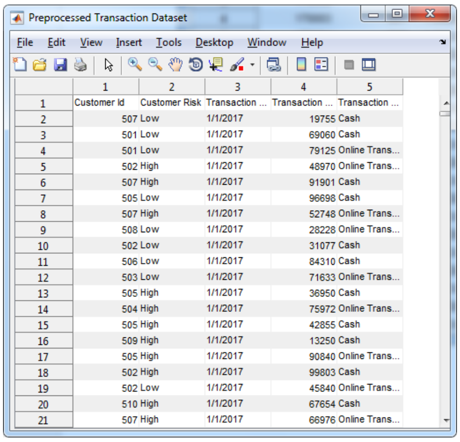


Bank Transaction Dataset

	1	2	3	4	5	6	7	8
1	Transaction Id	Customer Id	Customer Ac...	Customer Risk	Transaction ...	Transaction ...	Transaction ...	Transaction ...
2	170001	507	1.0922e+09	Low	1/1/2017	19755	Cash	1.34.10
3	170002	501	1.0922e+09	Low	1/1/2017	69060	Cash	2.57.39
4	170003	501	1.0922e+09	Low	1/1/2017	79125	Online Trans...	9.32.05
5	170004	502	1.0922e+09	High	1/1/2017	48970	Online Trans...	3.55.43
6	170005	507	1.0922e+09	High	1/1/2017	91901	Cash	8.08.42
7	170006	505	1.0922e+09	Low	1/1/2017	96698	Cash	8.43.22
8	170007	507	1.0922e+09	High	1/1/2017	52748	Online Trans...	0.54.20
9	170008	508	1.0922e+09	Low	1/1/2017	28228	Online Trans...	5.29.58
10	170009	502	1.0922e+09	Low	1/1/2017	31077	Cash	0.39.38
11	170010	506	1.0922e+09	Low	1/1/2017	84310	Cash	4.17.37
12	170011	503	1.0922e+09	Low	1/1/2017	71633	Online Trans...	5.24.09
13	170012	505	1.0922e+09	High	1/1/2017	36950	Cash	0.34.07
14	170013	504	1.0922e+09	High	1/1/2017	75972	Online Trans...	8.34.36
15	170014	505	1.0922e+09	High	1/1/2017	42855	Cash	2.07.24
16	170015	509	1.0922e+09	High	1/1/2017	13250	Cash	0.04.26
17	170016	505	1.0922e+09	High	1/1/2017	90840	Online Trans...	7.28.37
18	170017	502	1.0922e+09	High	1/1/2017	99803	Cash	2.28.56
19	170018	502	1.0922e+09	Low	1/1/2017	45840	Online Trans...	9.45.53
20	170019	510	1.0922e+09	High	1/1/2017	67654	Cash	7.59.52
21	170020	507	1.0922e+09	High	1/1/2017	66976	Online Trans...	9.57.37

Fig 3: Output list of initial dataset

The figure 4 shows the final transaction dataset:

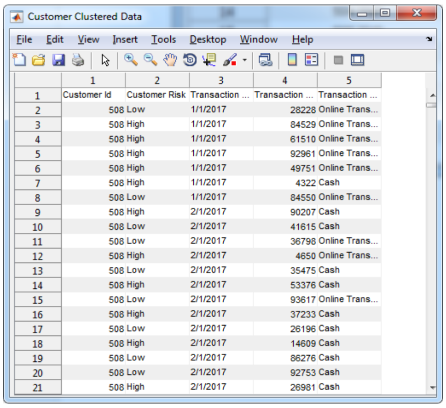


Preprocessed Transaction Dataset

	1	2	3	4	5
1	Customer Id	Customer Risk	Transaction ...	Transaction ...	Transaction ...
2	507	Low	1/1/2017	19755	Cash
3	501	Low	1/1/2017	69060	Cash
4	501	Low	1/1/2017	79125	Online Trans...
5	502	High	1/1/2017	48970	Online Trans...
6	507	High	1/1/2017	91901	Cash
7	505	Low	1/1/2017	96698	Cash
8	507	High	1/1/2017	52748	Online Trans...
9	508	Low	1/1/2017	28228	Online Trans...
10	502	Low	1/1/2017	31077	Cash
11	506	Low	1/1/2017	84310	Cash
12	503	Low	1/1/2017	71633	Online Trans...
13	505	High	1/1/2017	36950	Cash
14	504	High	1/1/2017	75972	Online Trans...
15	505	High	1/1/2017	42855	Cash
16	509	High	1/1/2017	13250	Cash
17	505	High	1/1/2017	90840	Online Trans...
18	502	High	1/1/2017	99803	Cash
19	502	Low	1/1/2017	45840	Online Trans...
20	510	High	1/1/2017	67654	Cash
21	507	High	1/1/2017	66976	Online Trans...

Fig 4: Final Transaction Dataset

-Next process is to cluster the customers report. The entire transaction details of each customer have been clustered as shown in Figure 5 below:

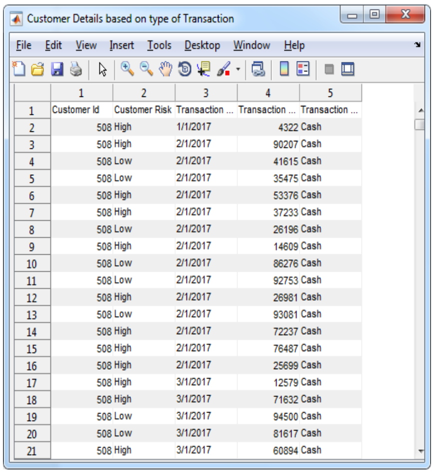


Customer Clustered Data

	1	2	3	4	5
1	Customer Id	Customer Risk	Transaction ...	Transaction ...	Transaction ...
2	508	Low	1/1/2017	28228	Online Trans...
3	508	High	1/1/2017	84529	Online Trans...
4	508	High	1/1/2017	61510	Online Trans...
5	508	High	1/1/2017	92961	Online Trans...
6	508	High	1/1/2017	49751	Online Trans...
7	508	High	1/1/2017	4322	Cash
8	508	Low	1/1/2017	84550	Online Trans...
9	508	High	2/1/2017	90207	Cash
10	508	Low	2/1/2017	41615	Cash
11	508	Low	2/1/2017	36798	Online Trans...
12	508	High	2/1/2017	4650	Online Trans...
13	508	Low	2/1/2017	35475	Cash
14	508	High	2/1/2017	53376	Cash
15	508	Low	2/1/2017	93617	Online Trans...
16	508	High	2/1/2017	37233	Cash
17	508	Low	2/1/2017	26196	Cash
18	508	High	2/1/2017	14609	Cash
19	508	Low	2/1/2017	86276	Cash
20	508	Low	2/1/2017	92753	Cash
21	508	High	2/1/2017	26981	Cash

Fig 5: Final Transaction Dataset

-Figure 6 shows the result of this selection process:

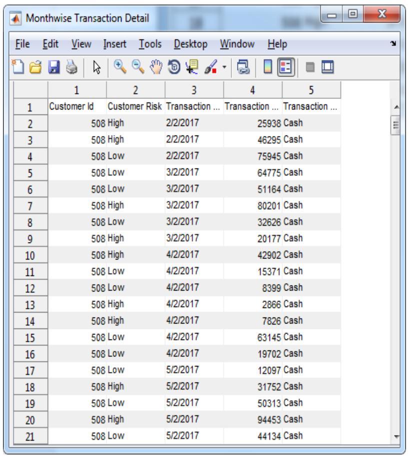


Customer Details based on type of Transaction

	1	2	3	4	5
1	Customer Id	Customer Risk	Transaction ...	Transaction ...	Transaction ...
2	508	High	1/1/2017	4322	Cash
3	508	High	2/1/2017	90207	Cash
4	508	Low	2/1/2017	41615	Cash
5	508	Low	2/1/2017	35475	Cash
6	508	High	2/1/2017	53376	Cash
7	508	High	2/1/2017	37233	Cash
8	508	Low	2/1/2017	26196	Cash
9	508	High	2/1/2017	14609	Cash
10	508	Low	2/1/2017	86276	Cash
11	508	Low	2/1/2017	92753	Cash
12	508	High	2/1/2017	26981	Cash
13	508	Low	2/1/2017	93081	Cash
14	508	High	2/1/2017	72237	Cash
15	508	High	2/1/2017	76487	Cash
16	508	High	2/1/2017	25699	Cash
17	508	High	3/1/2017	12579	Cash
18	508	High	3/1/2017	71632	Cash
19	508	Low	3/1/2017	94500	Cash
20	508	Low	3/1/2017	81617	Cash
21	508	High	3/1/2017	60894	Cash

Fig 6: Customer details based on the selection process

-Figure 7 shows the details of mutation details.



Monthwise Transaction Detail

	1	2	3	4	5
1	Customer Id	Customer Risk	Transaction ...	Transaction ...	Transaction ...
2	508	High	2/2/2017	25938	Cash
3	508	High	2/2/2017	46295	Cash
4	508	Low	2/2/2017	75945	Cash
5	508	Low	3/2/2017	64775	Cash
6	508	Low	3/2/2017	51164	Cash
7	508	High	3/2/2017	80201	Cash
8	508	Low	3/2/2017	32626	Cash
9	508	High	3/2/2017	20177	Cash
10	508	High	4/2/2017	42902	Cash
11	508	Low	4/2/2017	15371	Cash
12	508	Low	4/2/2017	8399	Cash
13	508	High	4/2/2017	2866	Cash
14	508	High	4/2/2017	7826	Cash
15	508	Low	4/2/2017	63145	Cash
16	508	Low	4/2/2017	19702	Cash
17	508	Low	5/2/2017	12097	Cash
18	508	High	5/2/2017	31752	Cash
19	508	Low	5/2/2017	50313	Cash
20	508	High	5/2/2017	94453	Cash
21	508	Low	5/2/2017	44134	Cash

Fig 7: Month wise transaction details

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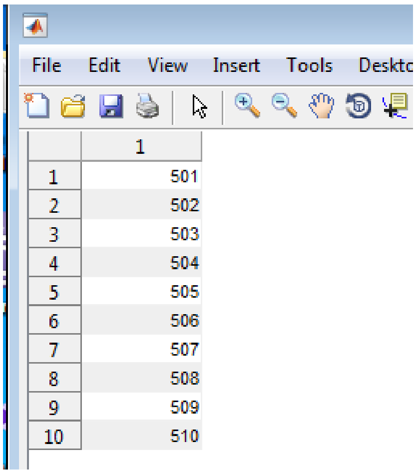
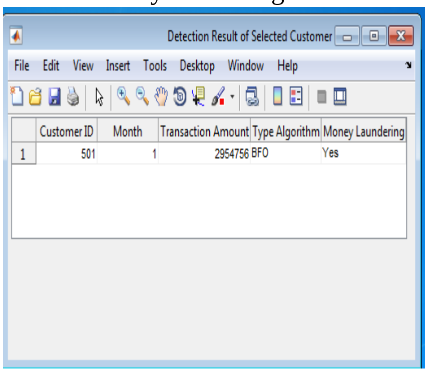
-Figure 8 represents the customers in the banking database under study.



	1
1	501
2	502
3	503
4	504
5	505
6	506
7	507
8	508
9	509
10	510

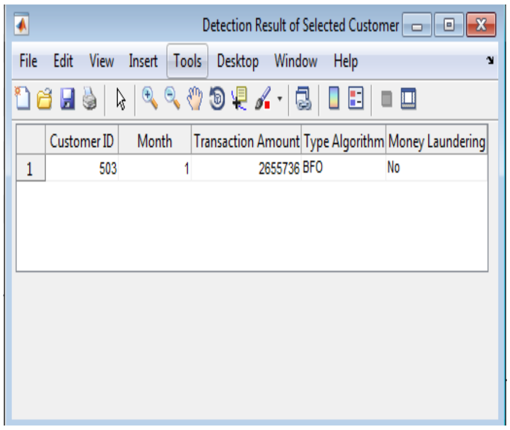
Fig 8: List of customer

From Figure 8. The customer selected for the study is selected to determine whether he is laundering money or not. The system has been implemented on two customers. Customer 501 and customer 503 where the system discovered that customer 501 is a money laundering situation as shown in Figure 9. The customer 503 is a normal case is not money laundering as shown in Figure 10.



	Customer ID	Month	Transaction Amount	Type Algorithm	Money Laundering
1	501	1	2954756	BFO	Yes

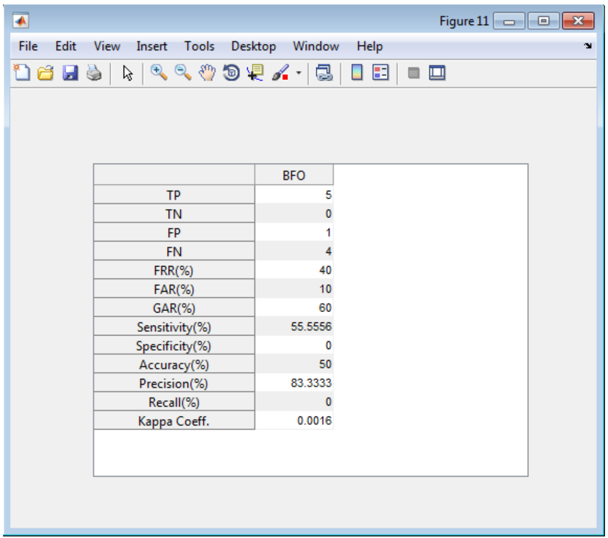
Fig 9: Money Laundering



	Customer ID	Month	Transaction Amount	Type Algorithm	Money Laundering
1	503	1	2655736	BFO	No

Fig 10: Not Money Laundering

-Figure 11 A set of performance measures were used to measure the efficiency of the algorithm as shown in Figure 11



	BFO
TP	5
TN	0
FP	1
FN	4
FRR(%)	40
FAR(%)	10
GAR(%)	60
Sensitivity(%)	55.5556
Specificity(%)	0
Accuracy(%)	50
Precision(%)	83.3333
Recall(%)	0
Kappa Coeff.	0.0016

Fig 11: Performance BA

X. CONCLUSION

Intelligent system is designed. Depending on the idea of the bacteria algorithm which is one of the evolutionary algorithms that are looking for the optimal solution. And the phenomenon of money-laundering aimed at turning dirty money into clean money. As money launderers began to use sophisticated methods to implement this process, and with the spread of modern technology has become easy to implement. Therefore, it was necessary to design modern systems to reduce this phenomenon, because classical methods are no longer useful in detecting these phenomena.

The system has been implemented on a banking database that includes a number of banking operations for a number of customers. The results were illustrated by the forms that emerged from the program.

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APPENDEX A

```
function fitness_val=BFO(fitval)
Ne=size(fitval,1);
Nr=size(fitval,1);
Nc=size(fitval,1);
Np=size(fitval,1);
Ns=size(fitval,2);
D=Ns;
C=0.01;
Ped=0.9;

population=fitval;

fitness_val=zeros(size(fitval,1),size(fitval,2));

for k=1:Np
   for i=1:Ns
       fitness_val(k,i)=sum(100*(1-
population(k,i)^2)^2+(population(k,i)-1)^2);
   end
end
last_fitness=fitness_val;

for l=1:Ne
   for k=1:Nr
Chemotaxis_fit=fitness_val;
       for j=1:Nc
          for i=1:Ns
             del=(rand(size(fitness_val,1),size(fitness_val,2))-
0.5)*2;

population(i)=population(i)+(C/sqrt(del(i)*del(i)'))*del(i);
             for d=1:D
                fitness_val(j,d)=sum(100*(1-
population(j,d)^2)^2+(population(j,d)-1)^2);
             end

             for m=1:Np
                if fitness_val(i)<last_fitness(i)
last_fitness(i)=fitness_val(i);

population(i)=population(i)+C*(del(i)/sqrt(del(i)*del(i)'));
                    for d=1:D
                       fitness_val(j,d)=sum(100*(1-
population(j,d)^2)^2+(population(j,d)-1)^2);
                    end
                else

del=(rand(size(fitness_val,1),size(fitness_val,2))-0.5)*2;

population(i)=population(i)+C*(del(i)/sqrt(del(i)*del(i)'));
                    for d=1:D
                       fitness_val(j,d)=sum(100*(1-
population(j,d)^2)^2+(population(j,d)-1)^2);
                    end
                 end
              end

           end

Chemotaxis_fit=[Chemotaxis_fitfitness_val];
       end  % End of Chemotapopulationis %


           for i=1:Np
Jhealth(i)=sum(Chemotaxis_fit(i,:));
           end
           [Jhealth1,I]=sort(Jhealth,'ascend');
populationmin=min(population);
    end
Jmin(l)=min(fitness_val);

  for i=1:Np
       r=rand;
       if r>=Ped
           for d=1:D
               fitness_val(i,d)=sum(100*(1-
population(i,d)^2)^2+(population(i,d)-1)^2);
           end
       end
    end

end
function
[cm,per,TP,TN,FP,FN,sens1,spec1,precision,recall,Jaccard_
coefficient,...

Dice_coefficient,kappa_coeff,acc1]=Performance_Analysis
(inp1,inp2)
global kpa
truelabel=inp1;
Recognition=inp2;
[cm grporder1]=confusionmat(truelabel,Recognition);
measure=zeros(4,size(cm,1));
for i = 1:size(cm,1)-1
    measure(1, i) = cm(i,i); % TP
    measure(2, i) = sum(cm(i,:))-cm(i,i); % FP
    measure(3, i) = sum(cm(:,i))-cm(i,i); % FN
    measure(4, i) = sum(cm(:)) - measure(3, i) - measure(2, i)
- measure(1, i);  % TN
end
TP=sum(measure(1, :));
FP=sum(measure(2, :));
FN=sum(measure(3, :));
TN=sum(measure(4, :));
precision = TP/(TP+FP)*100;
recall = TN/(TP+FN)*100;
```

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```
Jaccard_coefficient=(TP+TN)/(TP+TN+FP+FN)*100;
Dice_coefficient=(2*(TP+TN))/(FP+(2*(TP+TN))+FN)*10
0;
per = zeros(size(cm,1),3);
s=1;
for i=1:size(cm,1)
    per(i,1) = (sum(cm([1:(i-1)
(i+1):size(cm,1)],i))/sum(cm(:)))*100; % Percentage of
FRR-%
    per(i,2) = (sum(cm(i,[1:(i-1)
(i+1):size(cm,1)]))/sum(cm(:)))*100; % Percentage of
FAR-%
    per(i,3) = (100-per(i,1)); % Percentage of GAR-%
end
  sens1=TP/(TP+FN)*100;
  spec1=TN/(TN+FP)*100;
  acc1=(sum(diag(cm))/sum(cm(:)))*100;

po=acc1;
pe=( (precision.*(TP+FP))+(recall.*(FN+TN)) ) ./ (
(TP+TN+FP+FN).^2 );
  kappa=([( po-pe ) ./ ( 1-pe );( pe-po ) ./ ( 1-po )]);
kappa_coeff=max(kappa)/100;
```