Optimizing open banking in the age of digital transformation by the metaheuristic algorithms of the Firefly &FMO

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ABSTRACT

The digital world has disrupted entire sectors, such as publishing, media recording, commerce, and manufacturing, among others. The financial services sector is not being spared."Digital transformation" has been on the agenda of many executives and board rooms for quite a long time. But beyond the buzzword, it is often not clear what "digital transformation" means. Financial services have often interpreted "digital transformation" only as a means to provide access to some products via digital channels, online or mobile, or, alternatively, as a pure cost reduction initiative. Digital transformation is much more than that: it is an entire change in the company's business model.It involves putting the customer at the center and using digital platforms to build a new business and operating model around that, using both own or external products and services. In today's age, open banking and the use of APIs is one of the ways to enter the digital transformation into the banking industry.Therefore, in this article, after the introduction of open banking, two scenarios have been presented for the optimality of the open banking model by metaheuristic algorithms according to their similarity to the ecosystem of the banking industry, and finally, after examining the results of testing on the data It was concluded that the best platform is to use the second scenario based on the FMO algorithm in the design of open banking platforms.

Keywords:

digital transformation, open banking, metaheuristic algorithms, Firefly algorithm, FMO algorithm

1. Introduction

Open banking can be defined as a collaborative model in which banking data is shared through APIs between two or more unaffiliated parties to deliver enhanced capabilities to the marketplace. APIs have been used for decades, particularly in the United States, to enable personal financial management software, to present billing detail at bank websites and to connect developers to payments networks like Visa and MasterCard. To date, Open banking can be defined as a collaborative model in which banking data is shared through APIs between two or more unaffiliated parties to deliver enhanced capabilities to the marketplace. To date, however, these connections have been used primarily to share information rather than to transfer monetary balances however, these connections have been used primarily to share information rather than to transfer monetary balances.*(McKinney on Payments July 2017)*

The potential benefits of open banking are substantial: improved customer experience, new revenue streams, and a sustainable service model for traditionally underserved markets.(*Forbes,2020)*

Naturally, such advances are not quite as straightforward. Recent years have brought the development of digital ecosystems .WeChat and Alibaba in China being prime examples. As these ecosystems mature they begin to collide, and the inability to share data threatens to curtail innovation in business and operating models.

By giving customers control over their banking data, and the ability to share it with third parties, open banking will transform banking. It has also generated a renewed focus on privacy. Open banking will result in more entities accessing banking data, and banking data being transferred more often.

Traditional Banking:

Many banks and authorized deposit-taking institutions currently have rather messy technology stacks, where new systems have been incrementally added resulting in (wco2,2018)

- A myriad of systems for core and internal operations.
- Systems by multiple vendors with orthogonal capabilities.
- Systems that require strong security, robust integration, and auditing capability.
- Different types of users consuming different services

This usually results in the following issues:

- Multiple applications are needed to carry out different operations within the bank
- Each application has a different account/login
- Disconnected experience through different channels of delivery
- No centralized platform to collect data on customer experience
- Limited or no external facing APIs for consumption from outside the organization

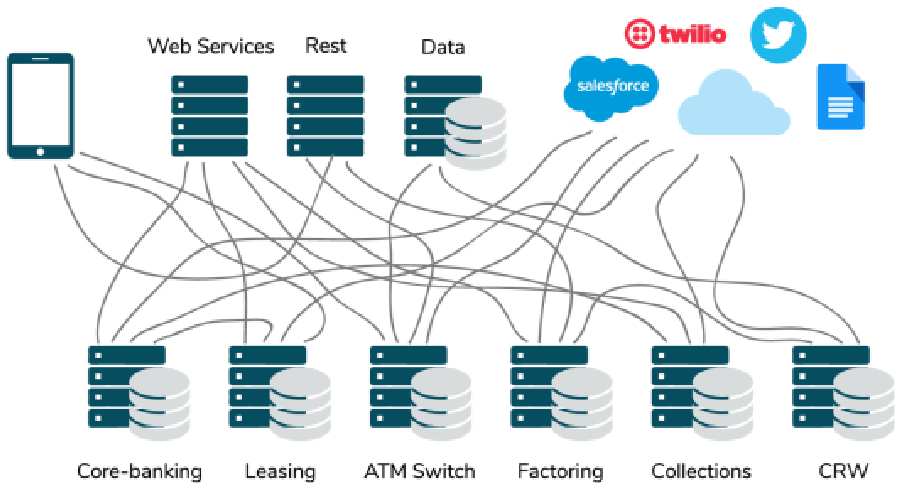

Fig1: Atypical architecture in a traditional bank (Annual report of the World Bank 2018 & wso2)

Spaghetti architecture found in most traditional banks makes it increasingly difficult to add new technology or update existing technology to add new services, without having an impact on the rest of the systems. Maintenance is also difficult, risky, and costly.(wco2,2020)

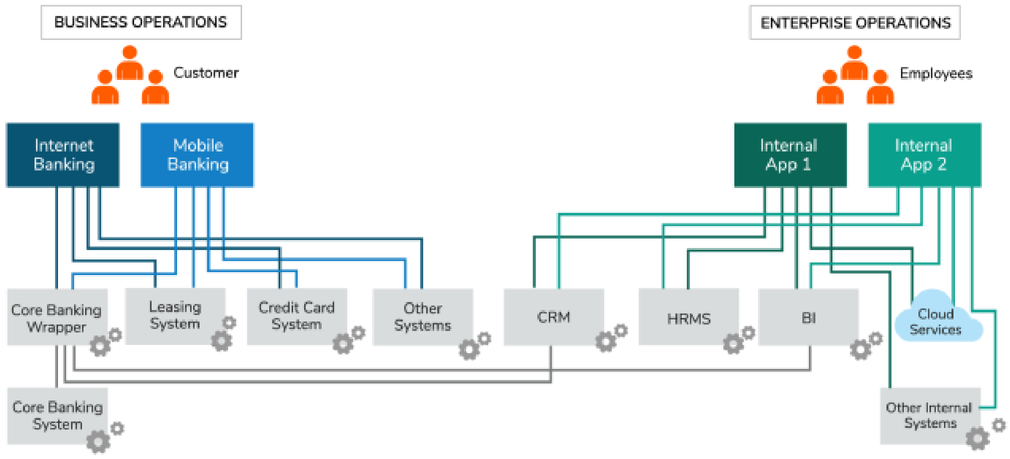

Fig2:systems integration in a traditional Bank (Deloitte 2020)

Modern Banking

Fundamental changes are currently taking place in the European private and corporate customer segment on the payments market. The market is developing extraordinarily dynamically.

New technologies, new players such as third-party payment service providers, fundamental changes in legislation and changes on the supply and demand side are causing changes in market models. (Barrie et al. 2016, S. 2).

Future supply-side changes are likely to have an impact on the payment method mix, such as the growth in A2A payments and the replacement of cash and card transactions. New providers such as Account Information Service Providers (AISPs) and Payment Initiation Service Providers (PISPs) show greater "disruptive potential". They are also likely to drive innovation.

Changes in regulation and technology are forcing market participants to reconsider their strategic response to the future payments market. (Barrie et al. 2016, S. 3).

New technologies are being introduced, new and innovative players are emerging alongside consolidation, radical changes are being made to legislation and customers are showing changing payment behavior – the actual payment process is therefore increasingly becoming an integrated product. It is therefore essential for the different market participants to base their strategies on the best possible business model in order to be able to use the new revenue pools (Barrie et al. 2016, S. 7).

It is true that the revenue sharing in payments will change, but the value chain in EU payments is still traditionally controlled and managed by banking institutions. However, the available technologies reduce the transaction costs for the market-based coordination of individual processes and thus contribute to a massive splitting of the value chain.

Individual stages of value creation can – as part of a disintermediation process – be occupied by non-bank actors. In particular, however, only if this has a comparative advantage can achieve towards banking institutions in the production of the respective sub-process performance.

It points– illuminating the development trend – everything indicates that the value chain could be restructured in the near future (Riedl 2002, S. 372 ff.).

Especially in the payment initiation phase and in the payment transmission stage - due to the increasing occupation of customer interfaces and end devices by non-banks, so-called TTPs (Third Party Providers) or rather only a weak fulfillment of the original banking function, the information transformation - banks are subject to a very strong disintermediation pressure (Riedl 2002, S. 375).

In principle, the following sub-processes can be mentioned within the value chain of payment transactions (Moormann et al. 2016, Abschn. 2.1):

- payment initiation
- authorization
- Settlement (clearing) between the account-managing payment service providers of the payee and the payer
- Payment settlement (settlement) between the account-managing payment service providers of the payee and the payer
- Information from the payer and payee about the payment made
- Providing the equivalent of a payment to the payee
- Processing of payment complaints

With agreements and technical standards, payment systems ensure that these steps are carried out securely and reliably between all participants in a payment system.

These processes – together with the mentioned roles – represent the “eco-payment system”. Payment in itself is not an end in itself, accordingly this system is embedded in the extensive value chain, which includes the business and settlement processes – before and after a payment. The value-added chain begins as soon as the customer is addressed or when customers are looking for products, i.e. services. This also applies or subsequently when comparing different offers and selecting a product to buy, when placing orders, delivering goods and invoicing to the payment process, customer service or any complaints processing. Primary services in this context are information about current offers to the target group, provision of loyalty services and the evaluation of customer information for more targeted addressing of customer segments (Moormann et al. 2016, Abschn. 2.1).

Digital transformation:

Today, the paradigm shift in technological advancements has reshaped the global era of digitization. In this digital era, technology is continuously driving change in almost every industry. From job automation to service digitization, from virtual collaboration to smart homes, from cloud computing to data analytics, technology has become an integral, indispensable requirement for society and the business ecosystem.*(LeewayHertz,2022)*

Before defenition the digital transformation, it is important to understand exactly what the “digital” in digital transformation means. There are several definitions of “digital” *[Berman 2012; Auriga 2016]* but we utilize a definition developed by McKinsey which states that digital is less about any one process and more about how companies run their business *(Dorner and Edelman 2015)*. McKinsey’s definition of “digital” can be broken down into three primary foci:

- Creating value at the new frontiers of the business world
- Optimizing the processes that directly affect the customer experience
- Building foundational capabilities that support the entire overall business initiative

Digital transformation defined by Westerman the use of technology to radically improve the performance or reach of enterprises.*(Westerman,2011)*

The spread of new payment instruments, the unstoppable technological evolution and the new European directives, including PSD2 (Payment Services Directive 2), have opened up new scenarios for banks.

New digital competitors are threatening to erode their traditional value chain.*(McKinsey,2018)*

Table 1: Selected definitions of the term “digital transformation(Bernardo Nicoletti 2021)”

Reference	Definition
BMWi	Digitization stands for the complete networking of all sectors of the economy and society, as well as the ability to collect relevant information, and to analyze and translate this information into actions. The changes bring advantages and opportunities, but they create completely new challenges.
Bowersox et al.(2005: 22ff)	Digital Business Transformation is a “process of reinventing a business to digitize operations and formulate extended supply chain relationships. The DBT [Digital Business Transformation] leadership challenge is about reenergizing businesses that may already be successful to capture the full potential of information technology across the total supply chain”
Westerman et al.(2011: 5)	“Digital Transformation (DT)—the use of technology to radically improve the performance or reach of enterprises—is becoming a hot topic for companies across the globe. Executives in all industries are

Reference	Definition
	using digital advances such as analytics, mobility, social media, and smart embedded devices—and improving their use of traditional technologies such as ERP—to change customer relationships, internal processes, and value propositions"
Mazzone (2014: 8)	"Digital Transformation is the deliberate and ongoing digital evolution of a company, business model, idea process, or methodology, both strategically and tactically"
PwC (2013: 9)	Digital transformation describes the fundamental transformation of the entire business world through the establishment of new technologies based on the internet with a fundamental impact on society as a whole
Bouee´ and Schaible	We understand digital transformation as a consistent networking of all sectors of the economy and adjustment of the players to the new realities of the digital economy. Decisions in networked systems include data exchange and analysis, calculation and evaluation of options, as well as initiation of actions and introduction of consequences

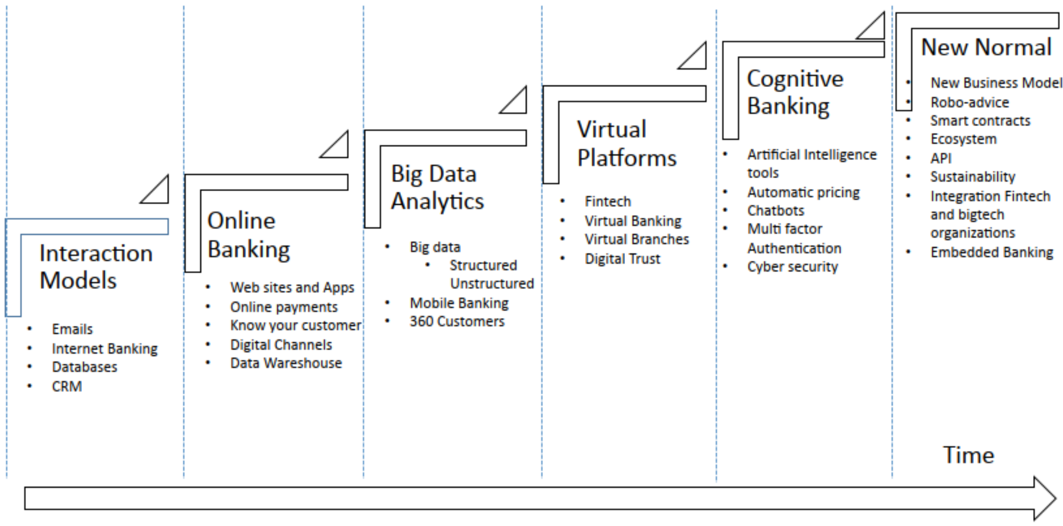

Fig.3. Digital banking evolution (Bernardo Nicoletti 2021)

Open Banking

Open banking is an emerging trend in the financial services industry that is opening the door for third party providers (TPPs) to offer a wide variety of new services – and it is poised to change the traditional retail banking model as we know it. Using open banking, financial institutions can securely provide other financial institutions and TPPs with seamless access to, and communication with, customer data through a standards-based technology called.*(PWC,2018)*

We are once again facing digital transformation the likes of which we haven't seen in a decade. Ten years ago, 80 percent of a financial institution's features came from connectivity to its core banking systems.

Today, that number has dropped to less than 30 percent. This means that most of the apps and solutions that consumers demand come from multiple third-party vendors, connecting not at the core system, but in digital channels. Because of this, having an open banking ecosystem has become crucial.*(BAI,2019)*

Open banking is the practice of sharing financial information electronically, securely and only under conditions of which customers approve. All financial institutions, regardless of size or IT environment, will need to pursue open banking standards and application programming interfaces (APIs) that allow third parties e icient access to financial information. .(FINASTRA,2020)

Banks can re-use the integration layer and the API management technology used for the open banking requirement to transform their existing architecture to a more structured, digitized architecture by following the below steps:

- • Integrate all systems with each other via a common integration layer.

- Create two separate integration clusters for business and enterprise systems.
- Standardize API and service interfaces to consume services.
- Expose legacy systems as web services via the integration layer.
- Create an API catalog and documentation for better service discovery and easier
- adoption.
- Manage throttling and rate limiting on services exposed.
- Introduce RBAC (Role Based Access Control) and ABAC (Asset Based Access Control)for service invocations.

By combining these digitally savvy architectures, banks end up with an infrastructure that is lean, agile and provides all stakeholders in the banking ecosystems with an optimal experience.

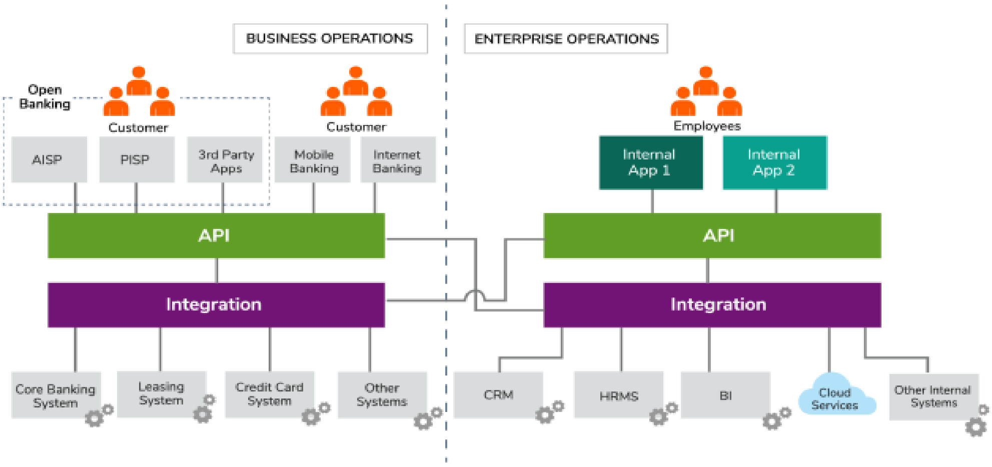

Fig4: system integration in a digital bank **(World Bank 2018&wso2)**

Open banking opens pathways to digital transformation

Digital transformation has arrived in many sectors, and you would expect, banking is one of them. Major organizations in the sector are starting to adapt to the new requirements and needs of their customers, with the purpose of improving their user experience.

The digital transformation of a bank can be built upon the rich resource of consolidated financial information of all banking consumers within a banking ecosystem.

Banks that offer AISP/PISP services gain access into this rich repository of consolidated financial information of its customers spread across multiple banks, obtaining a much deeper understanding of its customer base than was possible before. Additionally, such a bank also receives consolidated financial data about its non-customers, thereby gaining valuable insights into market segments that the bank can eventually tap into and expand

its portfolio. Apart from gaining deeper insights into the bank's customers and noncustomers, the repository of customer financial data enables a bank to provide new products and services that will translate into new revenue streams for the respective bank.

Digital transformation partnership for banking beyond the norm:

- Web and mobile app suite that enables customer-centric digital services
- Insight sales application that provides capabilities to transform the customer data repository into business insights
- Extensive analytics to collate data from various APIs and create products and services for insights-based selling
- Platform capabilities to build complete technologies that seamlessly integrate with existing and new systems
- A collaborative effort towards digital transformation that encapsulates all functions of an organization.

Proposed Methodology: Two scenarios proposed in this article with meta-heuristic algorithms

The cooperation of banks with open banking platforms is considered as the axis of uncertainty due to the high uncertainty and the high effect on the open banking ecosystem.

Banks often face challenges when facing the open banking approach and changing their business model to a platform model, and with the aim of benefiting from the advantages of the platform model such as more sources of income, more and faster innovations and Future growth, adopt this approach.

But the approaches that can be adopted in facing the platform model are the creation of each bank's own open banking platform or cooperation to form one or two main platforms.

First scenario :(Using a banking platform that is better)

In this scenario, an open banking platform is responsible for receiving access and attracting the participation of banks and other providers, and during processing processes, it provides integrated products and open banking Attractiveness applications according to the needs of customers.

The key feature of this approach in the age of digital transformation is the similarity of open banking in this scenario due to the uniqueness of fireflies in being attracted by each other. In this way, banks are attracted to each other due to the greater ability of digital transformation to provide services to customers.

With this approach, any bank that has digital features and provides services to customers in this way, is integrated with other similar banks in terms of digital capability to provide services and can provide services using the top bank platform.

According to this scenario, the bank that provided the best platform in terms of digital transformation ability will attract other banks to its side in providing services and all of them will provide better services on that bank's platform.

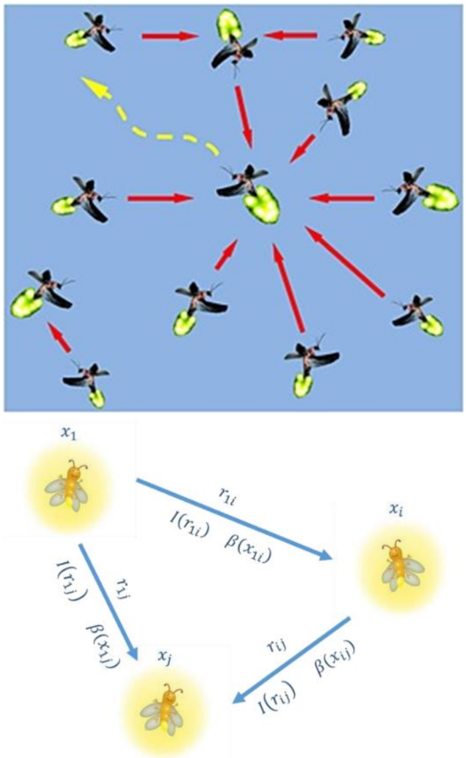

Fig 5. Attractiveness with firefly algorithm

The second scenario: (single digital transformation platform for open banking)

Fig 6: An Efficient Moth Flam Algorithm for single open banking

In this scenario, each bank does not have its own platform, but there is a single digital transformation platform that all banks use and draw upon to offer their services to Provide customers.
In this scenario, using the Moth-Flame algorithm to attract butterflies to the candle light, the simulation of open banking in using a single platform is investigated.

Firefly Algorithm

Now we can idealize some of the flashing characteristics of fireflies so as to develop firefly-inspired algorithms. For simplicity in describing our new Fire-fire Algorithm (FA) which was developed by Xin-She Yang at Cambridge University in 2007, we now use the following three idealized rules:

- All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex;
- Attractiveness is proportional to the their brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one. The attractiveness is proportional to the brightness and they both decrease as their distance increases. If there is no brighter one than a particular firefly, it will move randomly;
- The brightness of a firefly is affected or determined by the landscape of the objective function.

For a maximization problem, the brightness can simply be proportional to the value of the objective function. Other forms of brightness can be defined in a similar way to the fitness function in genetic algorithms.
assume that the attractiveness of a firefly is determined by its brightness which in turn is associated with the encoded objective function.

In the simplest case for maximum optimization problems, the brightness / of a firefly at a particular location x can be chosen as I(x) ∝ f(x). However, the attractiveness ß is relative, it should be seen in the eyes of the beholder or judged by the other fireflies. Thus, it will vary with the distance r_{ij} between firefly i and firefly . In addition, light intensity decreases with the distance from its source, and light is also absorbed in the media, so we should allow the attractiveness to vary with the degree of absorption.

In the simplest form, the light intensity $I(r)$ varies according to the inverse square law

$I(r) = \frac{I_s}{r^2}$(7.1)

where I_s is the intensity at the source. For a given medium with a fixed light absorption coefficient γ, the light intensity I varies with the distance r. That is

$I = I_0 e^{-\gamma r}$(7.2)

where I_0 is the original light intensity. In order to avoid the singularity at r = 0 in the expression I_s/r^2, the combined effect of both the inverse square law and absorption can be approximated as the following Gaussian form

$I(r) = I_0 e^{-\gamma r^2}$(7.3)

As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, we can now define the attractiveness ß of a firefly by

$\beta = \beta_0 e^{-er^2}$(7.4)

where β_0 is the attractiveness at $r = 0$. As it is often faster to calculate $1/(1 + r^2)$ than an exponential function, the above function, if necessary, can conveniently be approximated as

$\beta = \frac{\beta_0}{1+\gamma r^2}$ (7.5)

Both (5.4) and (5.5) define a characteristic distance $\Gamma = l/\sqrt{\gamma}$ over which the attractiveness changes significantly from ß$_0$ to $\beta_0 e^{-1}$ for equation (5.4) or $\beta_0/2$ for equation (7.5).
In the actual implementation, the attractiveness function ß(r) can be any monotonically decreasing functions such as the following generalized form

$\beta(r) = \beta_0 e^{-\gamma r^m}$, $m \geq 1$ (7.6)

For a fixed γ, the characteristic length becomes

$\Gamma = \gamma^{-1/m} \to 1, \quad m \to \infty$ (7.7)

Conversely, for a given length scale Γ in an optimization problem, the param-eter γ can be used as a typical initial value. That is

$\gamma = \frac{1}{\Gamma^m}$ (7.8)

The distance between any two fireflies i and j at x_i, and x_j, respectively, is the Cartesian distance

$r_{ij} = \|x_i - x_j\| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2}$ (7.9) where $x_{i,k}$ is the kth component of the spatial coordinate x_i of ith firefly. In 2-D case, we have

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (7.10)$$

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

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2}(x_j - x_i) + \alpha\epsilon_i \qquad (7.11)$$

where the second term is due to the attraction. The third term is randomiza-tion with α being the randomization parameter, and ϵ_i is a vector of random numbers drawn from a Gaussian distribution or uniform distribution. For example, the simplest form is ϵ_i and can be replaced by $rand - 1/2$ where $rand$ is a random number generator uniformly distributed in [0,1], For most of our implementation, we can take $ß_0 = 0$ = 1 and $\alpha \in$ [0,1].

It is worth pointing out that (5.11) is a random walk biased towards the brighter fireflies. If $ß_0 = 0$, it becomes a simple random walk. Furthermore, the randomization term can easily be extended to other distributions such as Levy flights.

The parameter γ now characterizes the variation of the attractiveness, and its value is crucially important in determining the speed of the convergence and how the FA algorithm behaves. In theory, $\gamma \in$ [0, ∞), but in practice, γ = O(l) is determined by the characteristic length Γ of the system to be optimized. Thus, in most application, it typically varies from 0.1 to 10.

Moth Flam Algorithm

MFO algorithm(Seyedali Mirjalili)

In the proposed MFO algorithm, we assume that the candidate solutions are moths and the problem's variables are the position of moths in the space. Therefore, the moths can fly in 1-D, 2-D, 3-D, or hyper dimensional space with changing their position vectors. Since the MFO algorithm is a population-based algorithm, we represent the set of moths in a matrix as follows:

$$M = \begin{bmatrix} m_{1,1} & m_{2,2} & \cdots & \cdots & m_{1,d} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{n,1} & m_{n,1} & \cdots & \cdots & m_{n,d} \end{bmatrix} (7.12)$$

where n is the number of moths and d is the number of variables (dimension).

For all the moths, we also assume that there is an array for storing the corresponding fitness values as follows:

$$OM = \begin{bmatrix} OM_1 \\ OM_2 \\ \vdots \\ OM_n \end{bmatrix} (7.13)$$

where n is the number of moths.

Note that the fitness value is the return value of the fitness (objective) function for each moth.

The position vector (first row in the matrix M for instance) of each moth is passed to the fitness function and the output of the fitness function is assigned to the corresponding moth as its fitness function (OM_1 in the matrix OM for instance).

Another key components in the proposed algorithm are flames. We consider a matrix similar to the moth matrix as follows:

$$F = \begin{bmatrix} F_{1,1} & F_{2,2} & \cdots & \cdots & F_{1,D} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ F_{n,1} & F_{n,1} & \cdots & \cdots & F_{n,d} \end{bmatrix} (7.14)$$

where n is the number of moths and d is the number of variables (dimension).It may be seen in Equation (7,14) that the dimension of M and F arrays are equal. For the flames, we also assume that there is an array for storing the corresponding fitness values as follows:

$$OF = \begin{bmatrix} OF_1 \\ OF_2 \\ \vdots \\ OF_n \end{bmatrix} (7.15)$$

where n is the number of moths.

It should be noted here that moths and flames are both solutions. The difference between them is the way we treat and update them in each iteration. The moths are actual search agents that move around the search space, whereas flames are the best position of moths that obtains so far.

In other words, flames can be considered as flags or pins that are dropped by moths when searching the search space. Therefore, each moth searches around a flag (flame) and updates it in case of finding a better solution. With this mechanism, a moth never lose its best solution.

The MFO algorithm is three-tuple that approximates the global optimal of the optimization problems and defined as follows:

$MFO = (I, P, T)$(7.16)

I is a function that generates a random population of moths and corresponding fitness values.

The methodical model of this function is as follows:

$I : \emptyset \rightarrow \{M, OM\}$(7.17)

The P function, which is the main function, moves the moths around the search space. This function received the matrix of M and returns its updated one eventually.

$P = M \rightarrow M$(7.18)

The T function returns true if the termination criterion is satisfied and false if the termination criterion is not satisfied:

$T : M \rightarrow \{true, false\}$(7.19)

With I, P, and T, the general framework of the MFO algorithm is defined as follows:

$M = I(\,);$
$\boldsymbol{while}\ T(M)\ is\ equal\ to\ false$
$\quad M = P(M);$
$\boldsymbol{end}$

The function **I** has to generate initial solutions and calculate the objective function values. Any random distribution can be used in this function. What we implement is as follows:

$\boldsymbol{for}\ i = 1 : n$
$\quad \boldsymbol{for}\ j = 1 : d$
$\quad\quad M(i,j) = (ub(i) - lb(i)) * rand() + lb(i);$
$\quad \boldsymbol{end}$
$\boldsymbol{end}$
$OM = FitnessFunction(M);$

As can be seen, there are two other arrays called ub and lb. These matrixes define the upper and lower bounds of the variables as follows:

$ub = [ub_1, ub_2, ub_3, \ldots, ub_{n-1}, ub_n]$(7.20)

where ub_i indicates the upper bound of the $i - th$ variable.

$Ib = [Ib_1, Ib_2, Ib_3, \ldots, Ib_{n-1}, Ib_n]$(7.21)

where ub_i indicates the lower bound of the $i - th$ variable.

After the initialization, the P function is iteratively run until the T function returns true. The P function is the main function that moves the moths around the search space. As mentioned above the inspiration of this algorithm is the transverse orientation. In order to mathematically model this behaviour, we update the position of each moth with respect to a flame using the following equation:

$M_i = S(M_i, F_j)$(7.22)

where M_i indicate the $i - th$ moth, F_j indicates the $j - th$ flame, and S is the spiral function.

We chose a logarithmic spiral as the main update mechanism of moths in this paper. However,any types of spiral can be utilized here subject to the following conditions:

- Spiral's initial point should start from the moth
- Spiral's final point should be the position of the flame
- Fluctuation of the range of spiral should not exceed from the search space

Considering these points, we define a logarithmic spiral for the MFO algorithm as follows:

$S(M_i, F_j) = D_i \, . e^{bt}. \cos(2\pi t) + F_j$(7.23)

Where D_i indicates the distance of the $i - th$ moth for the $j - th$ flame, b is a constant for defining the shape of the logarithmic spiral, and t is a random number in $[-1,1]$.

D is calculated as follows:

$D_i = |F_j - M_i|$(7.24)

where M_i indicate the $i - th$ moth, F_j indicates the $j - th$ flame, and D_i indicates the distance of the $j - th$ moth for the $j - th$ flame.

Equation (7.23) is where the spiral flying path of moths is simulated. As may be seen in this equation, the next position of a moth is defined with respect to a flame. The t parameter in the spiral equation defines how much the next position of the moth should be close to the flame ($t = -1$ is the closest position to the flame, while $t = 1$ shows the farthest). Therefore, a hyper ellipse can be assumed around the flame in all directions and the next position of the moth would be within this space. Spiral movement is the main component of the proposed method because it dictates how the moths update their positions around flames. The spiral equation allows a moth to fly "around" a flame and not necessarily in the space between them. Therefore, the exploration and exploitation of the search space can be guaranteed. The logarithmic spiral, space around the flame, and the position considering different t on the curve are illustrated in Fig. 7.

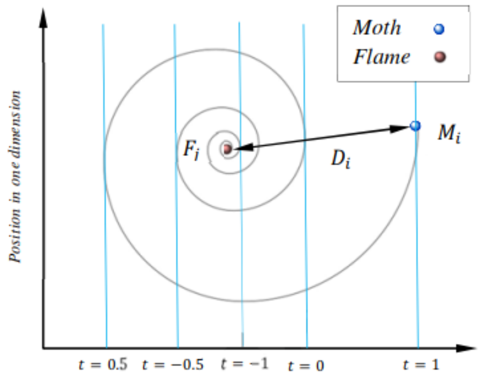

Figure 7. Logarithmic spiral, space around a flame, and the position with respect to t

Fig. 8 shows a conceptual model of position updating of a moth around a flame. Note that the vertical axis shows only one dimension (1 variable/parameter of a given problem), but the proposed method can be utilised for changing all the variables of the problem. The possible positions (dashed black lines) that can be chosen as the next position of the moth (blue horizontal line) around the flame (green horizontal line) in Fig. 8 clearly show that a moth can explore and exploit the search space around the flame in one dimension. Exploration occurs when the next position is outside the space between the moth and flam as can be seen in the arrows labelled by 1, 3, and 4. Exploitation happens when the next position lies inside the space between the moth and flame as can be observed in the arrow labelled by 2. There are some interesting observations for this model as follow:

- A moth can converge to any point in the neighbourhood of the flame by changing t
- The lower t, the closer distance to the flame.
- The frequency of position updating on both sides of the flame is increased as the moth get closer to the flame

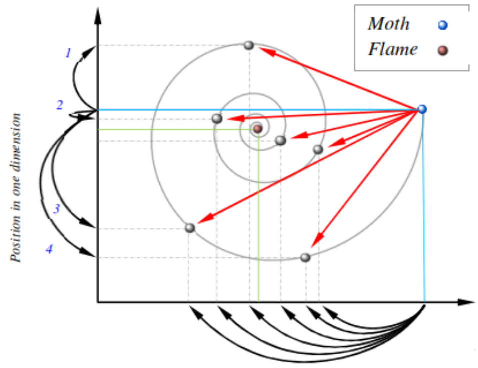

Figure 8. Some of the possible positions that can be reached by a moth with respect to a flame using the logarithmic spiral

The proposed position updating procedure can guarantee the exploitation around the flames. In order to improve the probability of finding better solutions, we consider the best solutions obtained so far as the flames. So, the matrix F in Equation (7.14) always includes n recent best solutions obtained so far. The moths are required to update their positions with respect to this matrix during optimization. In order to further emphasize exploitation, we assume that t is a random number in $[r, 1]$ where r is linearly decreased from -1 to -2 over the course of iteration. Note that we name r as the convergence constant. With this method, moths tend to exploit their corresponding flames more accurately proportional to the number of iterations.

A question that may rise here is that the position updating in Equation (7.23) only requires the moths to move towards a flame, yet it causes the MFO algorithm to be trapped in local optima quickly. In order to prevent this, each moth is obliged to update its position using only one of the flames in Equation (7.23). It each iteration and after updating the list of flames, the flames are sorted based on their fitness values. The moths then update their positions with respect to their corresponding flames. The first moth always updates its position with respect to the best flame, whereas the last moth updates its position with respect to the worst flame in the list. Fig. 9
shows how each moth is assigned to a flame in the list of flames.

It should be noted that this assumption is done for designing the MFO algorithm, while possibly it is not the actual behaviour of moths in nature. However, the transverse orientation is still done by the artificial moths. The reason that why a specific flame is assigned to each moth is to prevent local optimum stagnation. If all of the moths get attracted to a single flame, all of them converge to a point in the search spaces because they can only fly towards a flame and not outwards. Requiring them to move around different flames, however, causes higher exploration of the search space and lower probability of local optima stagnation.

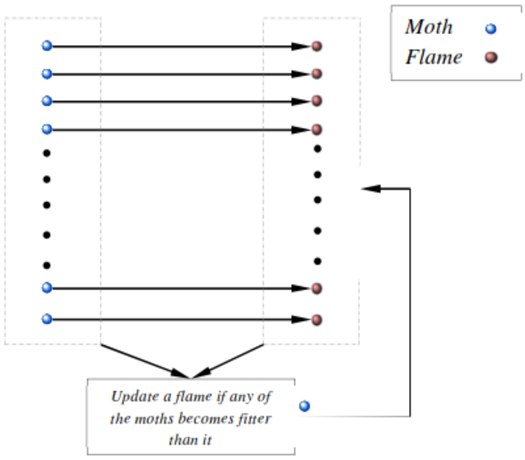

Figure 9. Each moth is assigned to a flame

Therefore, the exploration of the search space around the best locations obtained so far is guaranteed with this method due to the following reasons:

- Moths update their positions in hyper spheres around the best solutions obtained so far.
- The sequence of flames is changed based on the best solutions in each iteration, and the moths are required to update their positions with respect to the updated flames. Therefore, the position updating of moths may occur around different flames, a mechanism that causes sudden movement of moths in search space and promotes exploration.

Another concern here is that the position updating of moths with respect to n different locations in the search space may degrade the exploitation of the best promising solutions. To resolve this concern, we propose an adaptive mechanism for the number of flames. Fig. 10 shows that how the number of flames is adaptively decreased over the course of iterations. We use the following formula in this regard:

$$flame\ no = round\left(N - l * \frac{N-1}{T}\right) \quad (7.24)$$

where l is the current number of iteration, N is the maximum number of flames, and T indicates the maximum number of iterations.

The results of the analysis of the scenarios proposed in this article

In this article, the first scenario is analyzed according to the behavior of fireflies. Then, to analyze the optimality of open banking based on this scenario, firefly metaheuristic algorithm has been used.

1) Fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex:All the desired objects in this article are banks, regardless of the type of bank. The type of bank in this article refers to types of retail, corporate or other types of banks. Therefore, all banks are considered the same in terms of type.
2) The attractiveness is proportional to the brightness, and they both decrease as their distance increases: In this article, the attractiveness of fireflies in the algorithm for banks is considered the ability of digital transformation and providing digital services to customers.
3) For any two flashing fireflies, the less brighter one will move towards the brighter one: According to this firefly feature, In this Article every bank should be stronger in providing electronic services, the rest will be attracted to that bank to use API.
4) If there is no brighter one than a particular firefly, it will move randomly. In this Article, If there is no bank better than itself in providing digital transformation services, its movement on the path will be random.

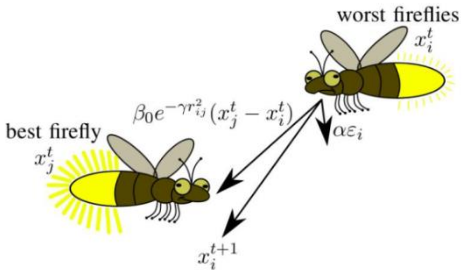

Fig7. Basic mechanism of the FA, use for First scenario in this Article

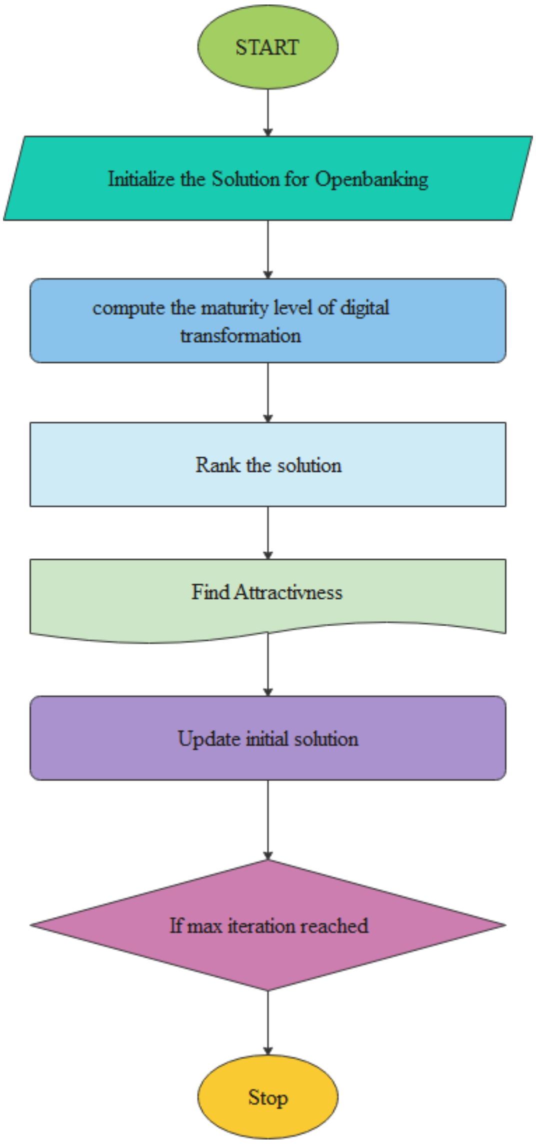

Fig8. Flowchart proposed for open banking in digital transformation age

```
%% Firefly Algorithm Main Loop

for it=1:MaxIt

    newpop=pop;
    for i=1:nPop
        for j=1:nPop
            if pop(j).Cost<=pop(i).Cost
                rij=norm(pop(i).Position-pop(j).Position);
                beta=beta0*exp(-gamma*rij^m);
                e=delta*unifrnd(-1,+1,VarSize);
                %e=delta*randn(VarSize);

                newpop(i).Position=pop(i).Position...
                    +beta*(pop(j).Position-pop(i).Position)...
                    +alpha*e;

                newpop(i).Position=max(newpop(i).Position,VarMin);
                newpop(i).Position=min(newpop(i).Position,VarMax);

                newpop(i).Cost=CostFunction(newpop(i).Position);

                if newpop(i).Cost<=BestSol.Cost
                    BestSol=newpop(i);
                end
            end
        end
```

Fig 9: Firefly Algorithm Main loop

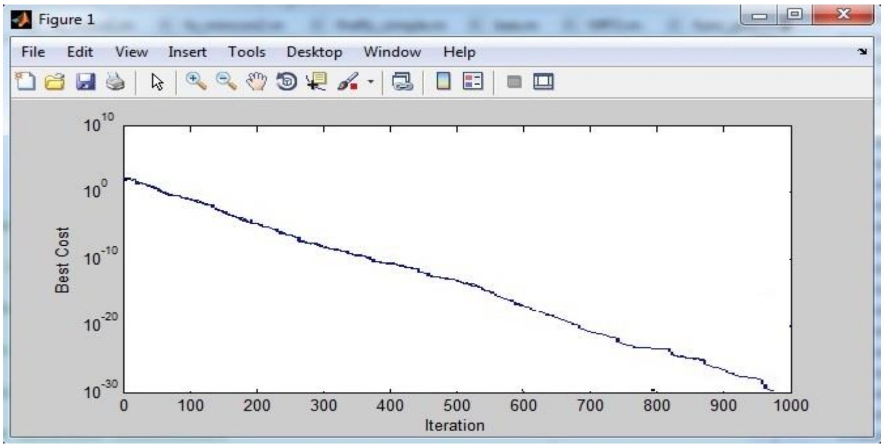

Fig 10. Number of flame is adaptively decreased over the course of iterations for open banking

Fig. 10 shows that there is N number of flames in the initial steps of iterations. However, the moths update their positions only with respect to the best flame in the final steps of iterations. The gradual decrement in number of flames balances exploration and exploitation of the search space. After all, the general steps of the P function are as follows.

$Update\ flame\ no\ using\ Equation\ (7.24)$
$OM = FitnessFunction(M);$
$\boldsymbol{if}\ iteration == 1$
$\quad F = sort(M);$
$\quad OF = sort(OM);$
$\boldsymbol{else}$
$\quad F = sort(Mt-1, Mt);$
$\quad OF = sort(Mt-1, Mt);$
$\boldsymbol{end}$

$for\ i = 1 : n$
    $for\ j = 1 : d$
        $Update\ r\ and\ t$
        $Calculate\ D\ using\ Equation\ (3.13)\ with\ respect\ to\ the\ corresponding\ moth$
        $Update\ M(i,j) using\ Eqs. (3.11) and\ (3.12) with\ respect$
        $to\ the\ corresponding\ moth$
    $\boldsymbol{end}$
$\boldsymbol{end}$

As discussed above the P function is executed until the T function returns true. After termination the P function, the best moth is returned as the best obtained approximation of the optimum**.**

Computational complexity of the MFO algorithm for open banking

Computation complexity of an algorithm is a key metric for evaluating its run time, which can be defined based on the structure and implementation of the algorithm. The computational complexity of the MFO algorithm depends on the number of moths (In This Article= Number of Banks), number of variables, maximum number of iterations, and sorting mechanism of flames in each iteration. Since we utilize Quicksort algorithm, the sort is of $O(nlogn)$ and $O(n^2)$ in the best and worst case, respectively. Considering the P function, therefore, the overall computational complexity is
defined as follows:
$O(MFO) = O(t(O(Quick\ sort) + O(position\ update)))$ (7.25)
$O(MFO) = O\big(t(n^2 + n \times d)\big) = O(tn^2 + tnd)$
(7.26)

where n is the number of moths (number of banks), t is the maximum number of iterations, and d is the number of variables.
To see how the MFO algorithm can theoretically be effective in solving optimization problems some observations are:
Procedure of updating positions allows obtaining neighboring solutions around the flames, a mechanism for mostly promoting exploitation.

- Since MFO utilizes a population of moths, local optima avoidance is high.
- Assigning each moth a flame and updating the sequence of flames in each iteration
- increase exploration of the search space and decreases the probability of local optima stagnation.
- Considering recent best solution obtained so far as the flames saves the promising solutions as the guides for moths.
- The best solutions are saved in the F matrix so they never get lost.
- Adaptive number of flames balances exploration and exploitation.
- Adaptive convergence constant (r) causes accelerated convergence around the flames over the course of iterations.

These observations make the MFO algorithm theoretically able to improve the initial random solutions and convergence to a better point in the search space.

Data Set for this Article

The data set is selected from the banker database and from the data of ten global banks that have an open banking platform with the variables of providing financial and banking services with 1000 iterations.
The number of data used is from a total of 10 selected banks of 1500 data, 500 of which are used for training and 1000 of which are used for testing, and were analyzed in the two scenarios proposed in this article and with the formulas proposed by the two firefly and FMO algorithms.

Result, Discussion and Comparison

After entering the data from open banking platforms from the banker data set belonging to 10 international banks in the software and checking them by two meta-heuristic algorithms Firefly and FMO, the results were obtained as follows.

Result of First scenario

In the first scenario of using the Firefly algorithm, with the passage of time and with the increase in the number of iterations, each of the actors of the open banking ecosystem, i.e. any bank or Firefly in the algorithm, which are more attractive in terms of digital transformation and having new technology in providing services to customers, others firefly (banks) also move towards them and the attraction of that firefly or bank becomes better and more attractive, and switching towards it happens more often.

And over time and with different iterations, there are more places in this algorithm. And also over time randomly with the increase of digitization capability that leads to the attractiveness of any bank or fire fly, repeating and switching permanently from a bank platform to the best platform is changing.

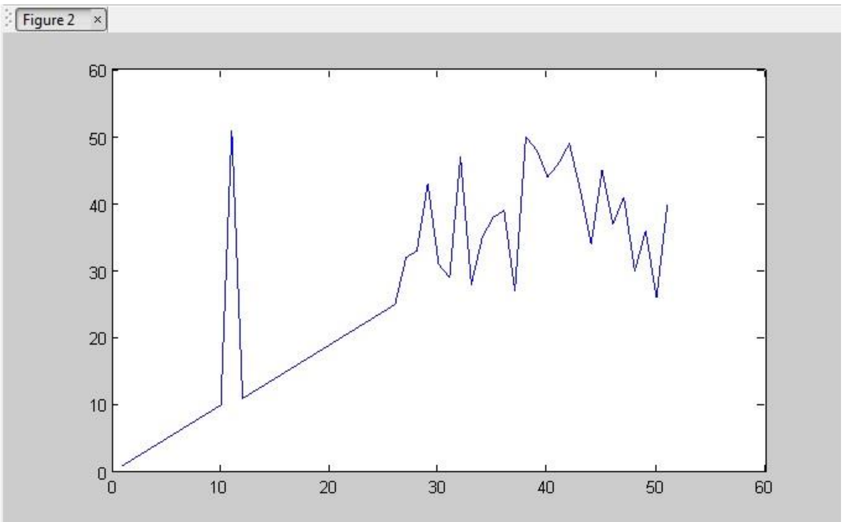

Fig 11. Volatility of open banking platform using the firefly algorithm

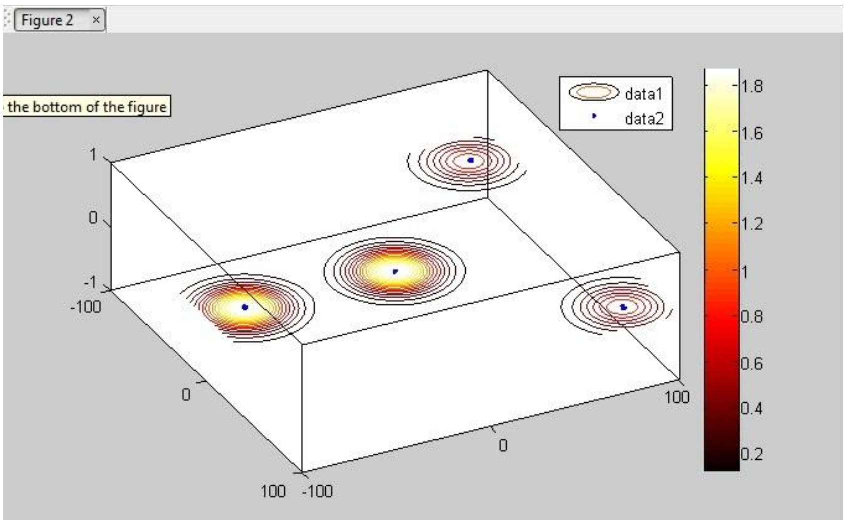

Fig 12: The movement of Fire fly in the first scenario towards the best platform

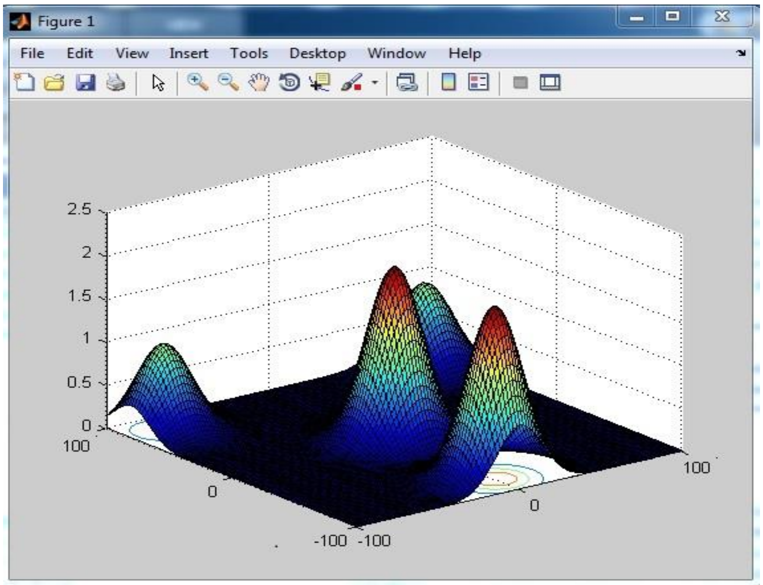

Fig 13: Frequent switching of banks to a better platform over a period of time and with more iterations

Result of Second scenario

In this scenario, there is a fixed platform, which is the flame, and according to the distance of each moth or bank to the flame, the optimal value is obtained. Therefore, the bank that is closer to the fixed platform in terms of digital capability is like a butterfly that is closer to the flame in this algorithm, so it is better.

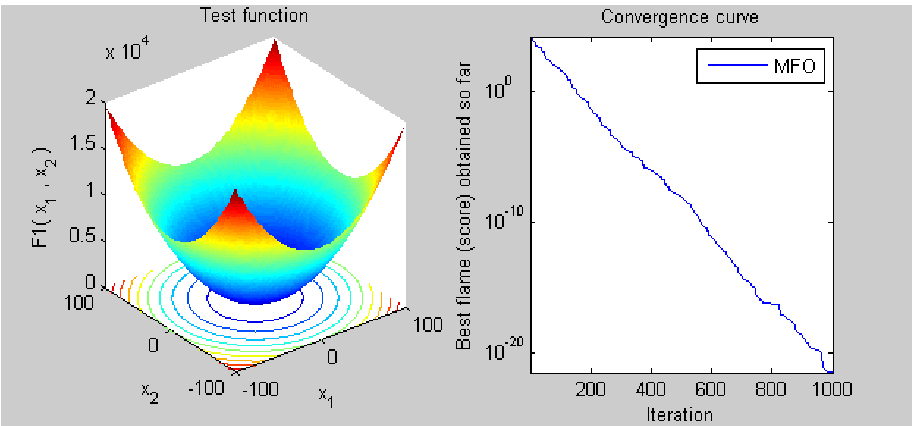

Fig 13: the distance of each moth or bank to the flame

Comparison of two scenarios and conclusions

By performing 1000 iterations on the data of 10 international banks using the Firefly and FMO algorithms, the following results were obtained. Figure 11 shows the iterations of data using the Firefly algorithm and Figure 12 shows the iterations of data using the FMO algorithm. The linear graph obtained from the two figures for open banking shows that using the FMO algorithm and the second scenario, we reach the optimal point faster.

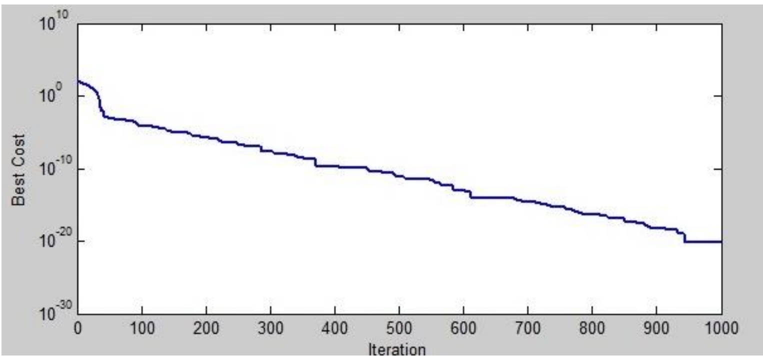

Fig 11: Firefly for open banking first scenario

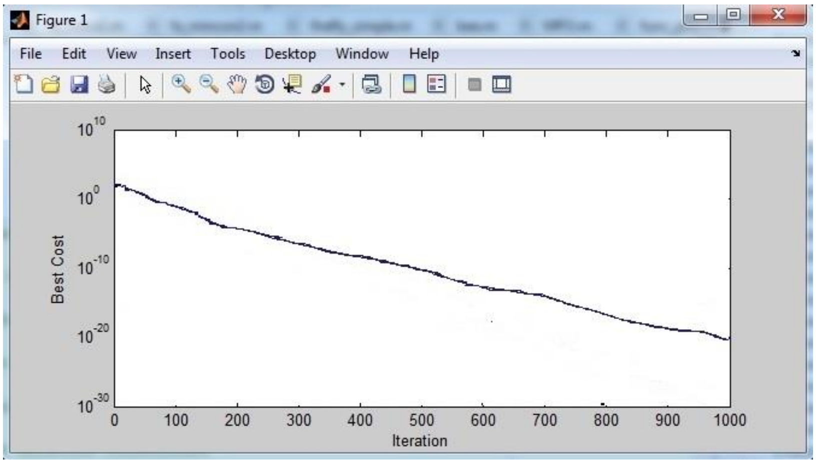

Fig 12: FMO for open banking second scenario

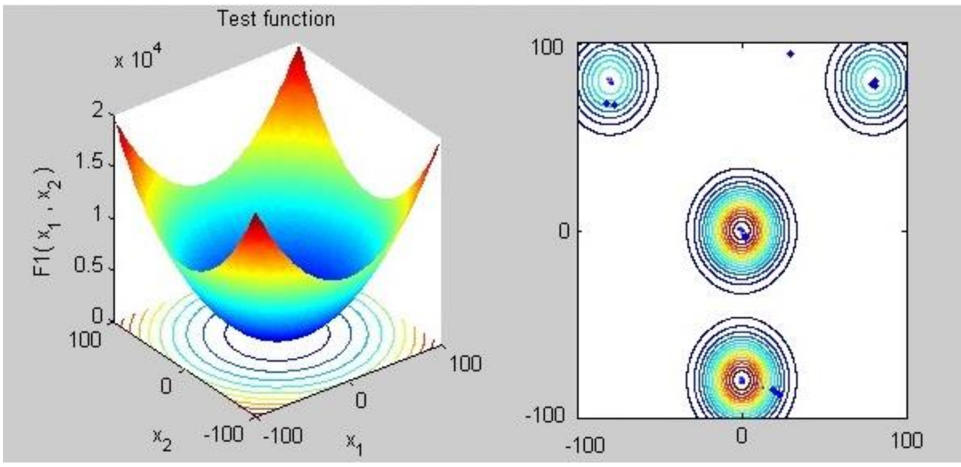

Fig 13: Comparison of two open banking scenarios with Firefly & FMO algorithms

Table 1: Comparison of the best situation of using open banking platforms with two algorithms, Firefly and FMO

	Iteration	Fire Fly (FA) Cost	Moth-flame optimization (MFO)
1.	50	0.01933	482.1928
2.	100	6.1091e-05	59.7345
3.	150	1.7181e-05	1.9555
4.	200	1.2902e-06	0.043772
5.	250	2.8977e-07	0.0021647
6.	300	1.7443e-08	9.7475e-05
7.	350	2.2998e-09	1.0032e-05
8.	400	4.7941e-10	1.0074e-06
9.	450	6.135e-11	8.3382e-08
10	500	8.2814e-12	1.0273e-08
11	550	9.3072e-13	4.0805e-10
12	600	1.2191e-13	8.1951e-12
13	650	1.5295e-14	3.5964e-13
14	700	2.6051e-15	7.1497e-15
15	750	1.9936e-16	2.1068e-16
16	800	4.8847e-17	5.2568e-17
17	850	3.2025e-18	4.5406e-18
18	900	1.5134e-18	2.3498e-19
19	950	3.2152e-20	1.6144e-20
20	1000	6.8576e-21	2.7135e-20

According to the results of the firefly and FMO algorithms in Table 1, we come to the conclusion that in open banking, the use of a single platform is similar to the FMO algorithm, which all banks are attracted to faster. And if they use new technologies and absorb digital transformation capabilities, they will be updated faster and use the same single platform.

But in the firefly scenario, with the introduction of new technologies and the more attractive platform of each bank, they undergo a rotational change in the platform used and as a result of the continuous changes of their platform over time.

Due to the fact that we are in the era of digital transformation and we are witnessing the increasing progress in the technologies used in banking. Therefore, the use of open banking platforms to provide services to customers will become widespread. However, each bank's use of a dedicated platform or changing the platform over time due to the advancement of technology is not optimal according to the modeling done, and the use of a single platform is more optimal according to the FMO algorithm model. Therefore, it is suggested to use a single platform in open banking.

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