EFFECT OF ROULETTE WHEEL SELECTION METHOD ON MAYFLY ALGORITHM

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Abstract: *The Mayfly algorithm is an optimization method that offers a powerful hybrid algorithm structure, based on the behavior of mayflies. It combines major advantages of particle swarm optimization, genetic algorithm, and firefly algorithm. Simulation experiments proved that it is capable of optimizing both the benchmark functions but not without notable limitations. Slow convergent rate, premature convergent, and potential imbalance between exploration and exploitation were among notable shortcomings, due to the random selection procedure used which allows the existing algorithm to exploit specific areas in the search space. This has made it difficult for the Mayfly algorithm to be used to solve high-dimensional problem spaces such as feature selection. In this study, the Mayfly algorithm is enhanced with the roulette wheel selection method which will replace the random selection method used in the existing Mayfly algorithm. Both the existing Mayfly algorithm and formulated enhanced Mayfly algorithm were used as feature selection on the face, iris, and fused face – iris recognition system in other to determine the effects of the roulette wheel selection method used in enhancing the existing Mayfly algorithm. Simulation experiments were carried out and the result showed high positive effects of the roulette wheel selection method as a good replacement for random selection used in the conventional Mayfly algorithm.*

I. INTRODUCTION

Identity verification, authorization, and accountability are the three main components of a security system [1]. Among these three components, identity verification is the most basic of these three elements, because it is the first [1], the process of establishing that a person is who they claim to be.

Several techniques have been developed for both identification and verification [6]. The security domain uses various authentication methods to keep information protected, the current method is biometrics. Biometrics could be viewed as a dual combination of technological and scientific authentication methods majorly based on human biology and extensively used in information assurance [7].

Ashish [1] emphasized that, in contrast to ancient authorization systems like smart cards, biometric technology acknowledges people through their identities instead of the things they carry. The function of the biometric system is to pick a reasonable biological characteristic for identification.

Optimization had been defined as a process of finding the best solution for a function (either its minimum or its maximum value [9]. Different optimization algorithm has been proposed in order to proffer solution to optimization problems. Notable algorithms such as particle swarm optimization (PSO), firefly algorithm (FA), ant colony optimization (ACO), genetic algorithm (GA), differential evolution (DE), etc. are some very popular optimizations algorithm. In this study, the Mayfly algorithm (MA) that was proposed within the year 2020 by Konstantinos Zervoudakis and Stelios Tsafarakis [4, 9] will be enhanced with the roulette wheel selection method.

Mayfly algorithm (MA) includes the mixture of options of particle swarm optimization (PSO), genetic algorithm (GA), and firefly algorithm (FA). Therefore is a hybrid improvement algorithm with high effectiveness, which models the mating practice pattern of mayflies [8, 10]. Xiaokai et al. [8] emphasized that this improved algorithm assumes that a Mayfly is associated adult when hatching and also the fittest one survives no matter the period of time, the algorithm was adopted, and it performed better in the global search than particle swarm optimization (PSO) [9].

Nevertheless, Zervoudakis and Tsafarakis [9] noted the limitation associated with the Mayfly algorithm, as it suffers from initial parameter standardization, which suggests that the performance of the Mayfly algorithm (MA), and also the performance of modified Mayfly algorithmic (MMA), are directly associated with the values of these parameters [9].

Slow convergent rate, premature convergent, and potential imbalance between exploration and exploitation were among notable shortcomings. Consequently, this study tends to improve the conventional Mayfly algorithm with the roulette wheel selection procedure, which will be a decent option to replace the random numbers used in the conventional Mayfly algorithm.

II. ROULETTE WHEEL SELECTION

The roulette-wheel selection is a commonly used selection procedure in genetic and evolutionary algorithms or in the modeling of complex networks [5]. The essential part of the choice process is to stochastically select from one generation to make the idea of the subsequent generation [2]. The requirement is that the fittest individuals have a greater chance of survival than weaker ones, this replicates nature therein fitter individuals will tend to possess a far better probability of survival and can proceed to make the mating pool for the subsequent generations. Also, weaker individuals are not without a chance [2].

Roulette wheel selection procedures assume the probability of selection is proportional to the fitness of an individual [5]. It is assumed N individuals, each characterized by its fitness wi > 0 (i = 1, 2, . . . , N). The selection probability of the i-th individual is thus given as

$$p_i = \frac{wi}{\sum_{i=1}^{N} wi} \qquad (i = 1, 2, \ldots, N). \qquad (1)$$

III. METHODOLOGY

In the Mayfly algorithm, to update velocities and solutions of males and females

$$V_{max} = rand * (x_{max} - x_{min}) \qquad (2)$$

$where\ rand \in (0,1)$
where $\boldsymbol{x_{max}}$ and $\boldsymbol{x_{min}}$ are the search space limits for the fitness function,

$$\boldsymbol{v_{ij}}^{t+1} = \begin{cases} \boldsymbol{v_{max}}, & \boldsymbol{if\ v_{ij}}^{t+1} > \boldsymbol{v_{max}} \\ -\boldsymbol{v_{max}}, & \boldsymbol{if\ v_{ij}}^{t+1} < -\boldsymbol{v_{max}} \end{cases}$$

$$\boldsymbol{v_{ij}}^{t+1} = \boldsymbol{g} * \boldsymbol{v_{ij}}^{t} + \boldsymbol{\alpha_1}\, e^{-\beta r_p^2}[\boldsymbol{pbest_{ij}} - \boldsymbol{x_{ij}}^{t}] + \boldsymbol{\alpha_2}\, e^{-\beta r_g^2}[\boldsymbol{gbest_j} - \boldsymbol{x_{ij}}^{t}] \qquad (3)$$

Where $\boldsymbol{\beta}$ is a fixed visibility coefficient that is used to limit a Mayfly's visibility to others, $\boldsymbol{r_p}$ is the Cartesian distance between $\boldsymbol{x_i}$ and $\boldsymbol{pbest_{ij}}$and $\boldsymbol{r_g}$ is the Cartesian distance between $\boldsymbol{x_i}$ and $\boldsymbol{gbest}$.

The distances are calculated as:

$$\|\boldsymbol{x_i} - \boldsymbol{X_i}\| = \sqrt{\sum_{j=1}^{n} (\boldsymbol{x_{ij}} - \boldsymbol{X_{ij}})^2} \qquad (4)$$

Where $\boldsymbol{x_{ij}}$ is the j^{th} element of Mayfly *i* and $\boldsymbol{X_{ij}}$ corresponds to $\boldsymbol{pbest_{ij}}$ or $\boldsymbol{gbest}$..

$$\boldsymbol{x_i}^{t+1} = \boldsymbol{x_i}^{t} + \boldsymbol{v_{ij}}^{t+1}$$

With $\boldsymbol{x_i}^{0} \sim \boldsymbol{U}(\boldsymbol{x_{min}}, \boldsymbol{x_{max}})$ male Mayfly

$$y_i^{t+1} = y_i^{t} + v_{ij}^{t+1}$$

With $y_i^{0} \sim U(y_{min}, y_{max})$ female Mayfly

$$v_{ij}^{t+1} = \begin{cases} v_{ij}^t + \alpha_2 e^{-\beta r_{mf}^2 (x_{ij}^t - y_{ij}^t)} & if\ f(y_i) > f(x_i) \\ v_{ij}^t + fl * r & if\ f(y_i) \le f(x_i) \end{cases} \quad (5)$$

Where v_{ij}^t is the velocity of female Mayfly i in dimension $j = 1, \ldots, n$ at time step t, y_{ij}^t the position of female Mayfly i in dimension j at time step t, α_2 is a positive attraction constant and β is a fixed visibility coefficient, while r_{mf} is the Cartesian distance between male and female mayflies, calculated using equation

$$V = \{V_1, V_2, \ldots, V_p\} \quad (6)$$

Finally, fl is a random walk coefficient, used when a female is not attracted by a male, so it flies randomly and r is a random value in the range of [-1, 1].

But in this study, roulette wheel selection methods were used to replace random selection used to model the attraction process, that is, females attracted by males in the convention Mayfly algorithm. By applying the roulette wheel selection procedure, the study aims to improve the existing Mayfly algorithm in terms of its accuracy, efficiency, and convergence behavior.

Updating velocities and solution of males and females using roulette wheel selection (p_i)

$$p_i = rand \le \frac{f(x_i^t)}{\sum_{i=1}^{N} f(x_i^t)} \quad (7)$$

$$V_{std} = p_i * (x_{std} - x_{mean}) \text{ where } rand \in (0, 1)$$

where x_{std} and x_{mean} are the search space limits for the fitness function,

$$v_{ij}^{t+1} = \begin{cases} v_{std}, & if\ v_{ij}^{t+1} > v_{std} \\ -v_{std}, & if\ v_{ij}^{t+1} < -v_{std} \end{cases}$$

$$v_{ij}^{t+1} = g * v_{ij}^{t} + \alpha_1 e^{-\beta r_p^2}[pbest_{ij} - x_{ij}^{t}] + \alpha_2 e^{-\beta r_g^2}[gbest_j - x_{ij}^{t}] \quad (8)$$

Where β is a fixed visibility coefficient that is used to limit a Mayfly's visibility to others, r_p is the Cartesian distance between x_i and $pbest_{ij}$ and r_g is the Cartesian distance between x_i and $gbest$.

The distances are calculated as:

$$\|x_i - X_i\| = \sqrt{\sum_{j=1}^{n} (x_{ij} - X_{ij})^2} \quad (9)$$

Where x_{ij} is the j^{th} element of Mayfly i and X_{ij} corresponds to $pbest_{ij}$ or $gbest$..

$$x_i^{t+1} = x_i^{t} + v_{ij}^{t+1}$$

With $x_i^{0} \sim U(x_{mean}, x_{std})$ male Mayfly

$$y_i^{t+1} = y_i^{t} + v_{ij}^{t+1}$$

With $y_i^{0} \sim U(y_{mean}, y_{std})$ female Mayfly

Using roulette wheel selection p_i

$$p_i = r \le \frac{f(x_i^t)}{\sum_{i=1}^{N} f(x_i^t)}$$

$$v_{ij}^{t+1} = \begin{cases} v_{ij}^t + \alpha_2 e^{-\beta r_{mf}^2 (x_{ij}^t - y_{ij}^t)} & if\ f(y_i) > f(x_i) \\ v_{ij}^t + fl * p_i & if\ f(y_i) \le f(x_i) \end{cases} \quad (10)$$

Where v_{ij}^t is the velocity of female Mayfly i in dimension $j = 1, \ldots, n$ at time step t, y_{ij}^t the position of female Mayfly i in dimension j at time step t , α_2 is a positive attraction constant and β is a fixed visibility coefficient, while r_{mf} is the Cartesian distance between male and female mayflies, calculated using equation $V = \{V_1, V_2, \ldots, V_p\}$. Finally, fl is a random walk coefficient, used when a female is not attracted by a male, so it flies deterministically by roulette wheel selection and r is a random value in the range of [-1, 1].

Evaluate Solutions $f(x) = f(x_i^{t+1})$ where $f: R^n \rightarrow R$ is the objective function that evaluates the quality of a solution.

IV. RESULT AND DISCUSSION

To determine the effect of the roulette wheel selection procedure as a good replacement for random selection used in conventional Mayfly algorithm.

The conventional Mayfly algorithm and enhanced Mayfly algorithm were used to select feature on face, iris, and fused face–iris recognition systems with modalities like Force

Acceptance Rate (FAR), Force Rejection Rate (FRR), Recognition Accuracy, and Recognition Time been considered.

Experimental result of the two feature selection techniques were thoroughly analyzed. Three hundred and forty-two (342) face and iris images were used for training which equals 60% of the total dataset and two hundred and twenty-eight (228) face and iris images which are equivalent to 40% of the total dataset were used for testing. The images were stored in JPEG (.jpg) format in other to be used for further analysis in the Matrix Laboratory of 2018(a) version.

The performance of each technique was affected by threshold values of 0.2, 0.35, 0.5, and 0.76. The optimum performance was achieved at a threshold value of 0.76 for all techniques with respect to single and fused features for both conventional Mayfly and Enhanced Mayfly algorithms using roulette wheel selection techniques.

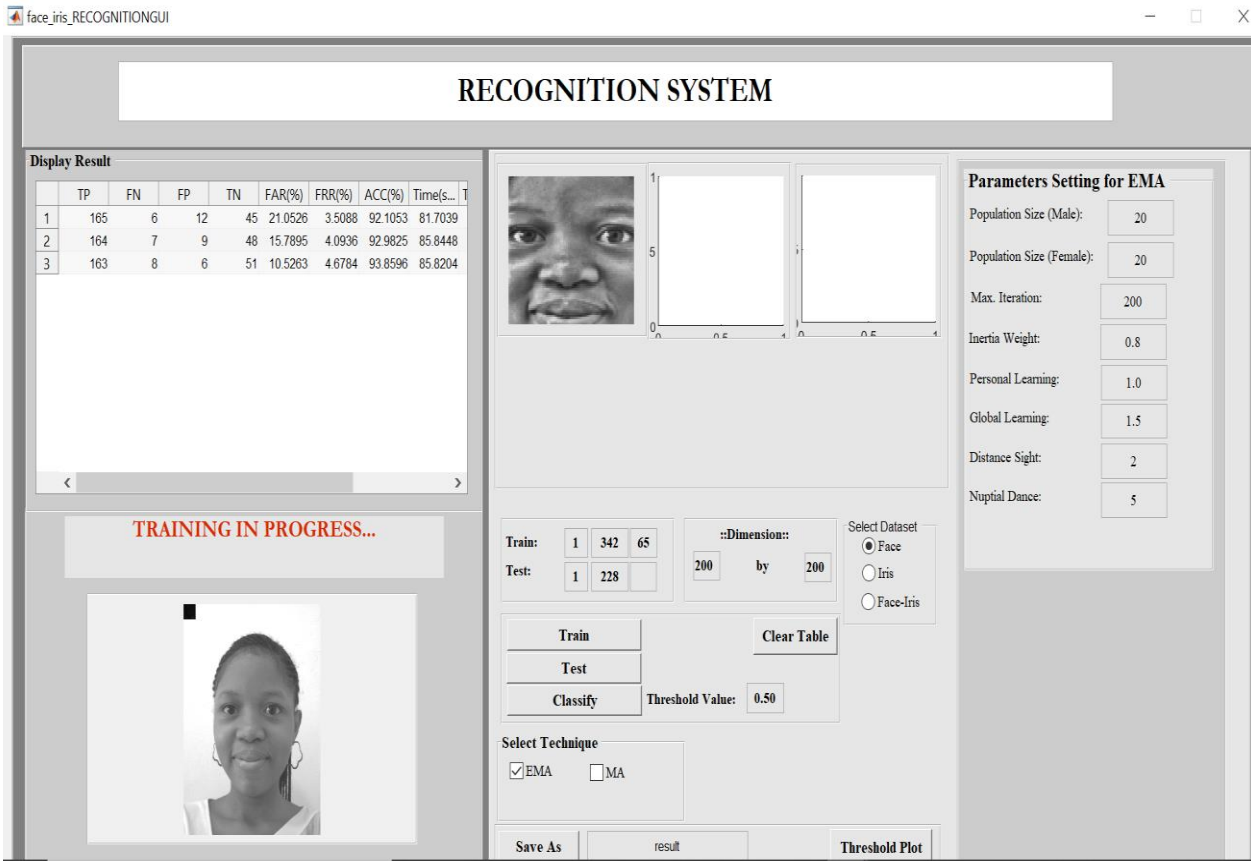

Fig. 1. Face, Iris, and fused face-iris recognition system

Table 1: Result obtained using Mayfly Algorithm (MA) with Random Selection at 0.76 threshold value

Modalities	Algorithm	FAR(%)	FRR(%)	ACC(%)	Time(sec)
Face – Iris	MA	3.51	5.26	95.18	213.75
Face	MA	7.02	8.77	91.67	103.07
Iris	MA	7.02	8.19	92.11	142.00

Table 2: Result obtained using Enhanced Mayfly algorithm (EMA) with Roulette Wheel Selection at 0.76 threshold value

Modalities	Algorithm	FAR(%)	FRR(%)	ACC(%)	Time(sec)
Face - Iris	EMA	1.79	2.92	97.36	181.52
Face	EMA	5.36	6.43	93.86	83.20
Iris	EMA	5.26	7.02	93.42	105.98

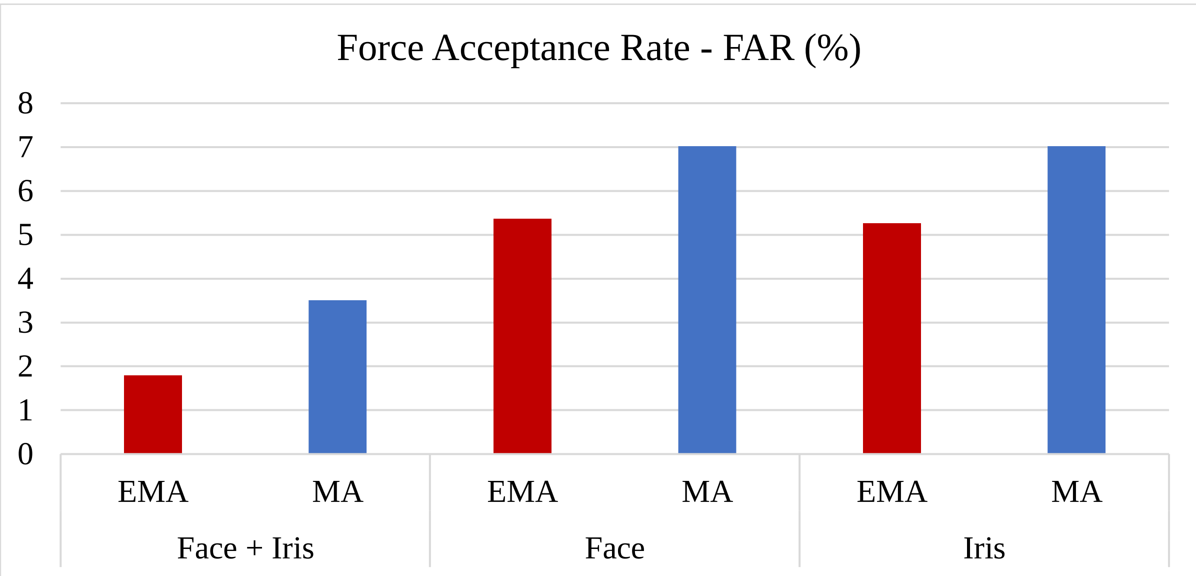

Fig. 2 Comparison of Mayfly Algorithm and Enhanced Mayfly Algorithm with roulette wheel selection at 0.76 threshold value (Force Acceptance Rate - FAR)

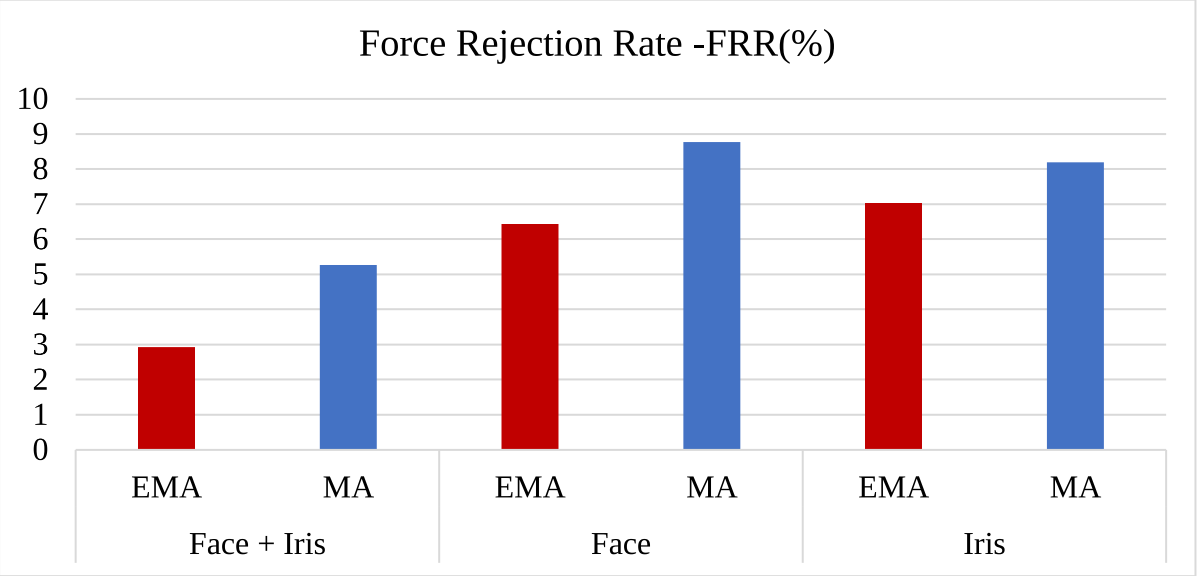

Fig. 3 Comparison of Mayfly Algorithm and Enhanced Mayfly Algorithm at 0.76 threshold value (Force Rejection Rate - FRR)

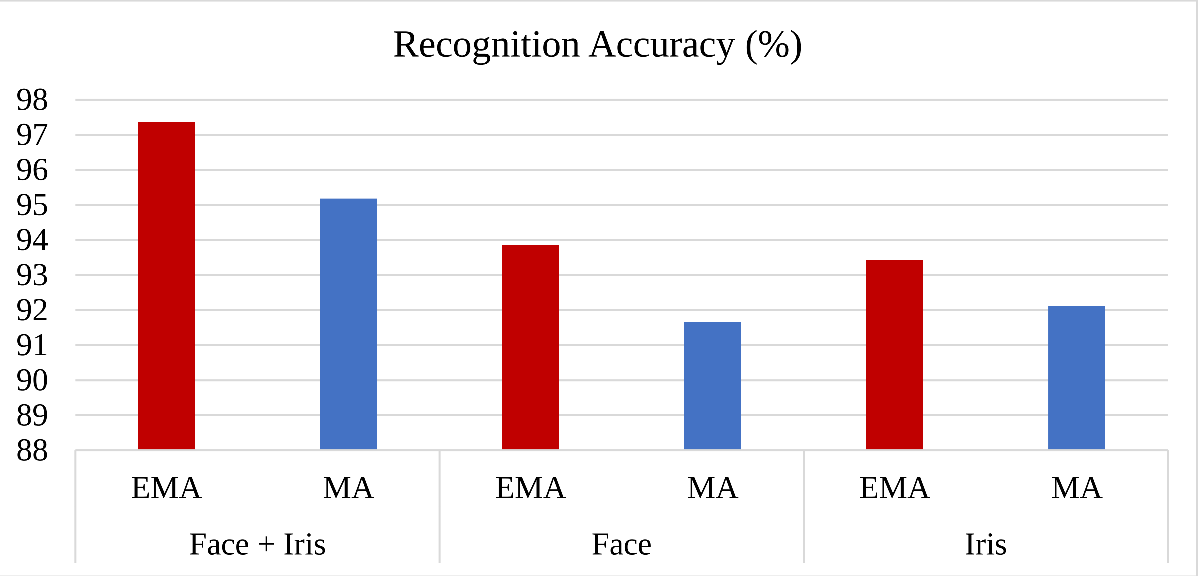

Fig. 4 Comparison of Mayfly Algorithm and Enhanced Mayfly Algorithm with roulette wheel selection at 0.76 threshold value (Recognition Accuracy)

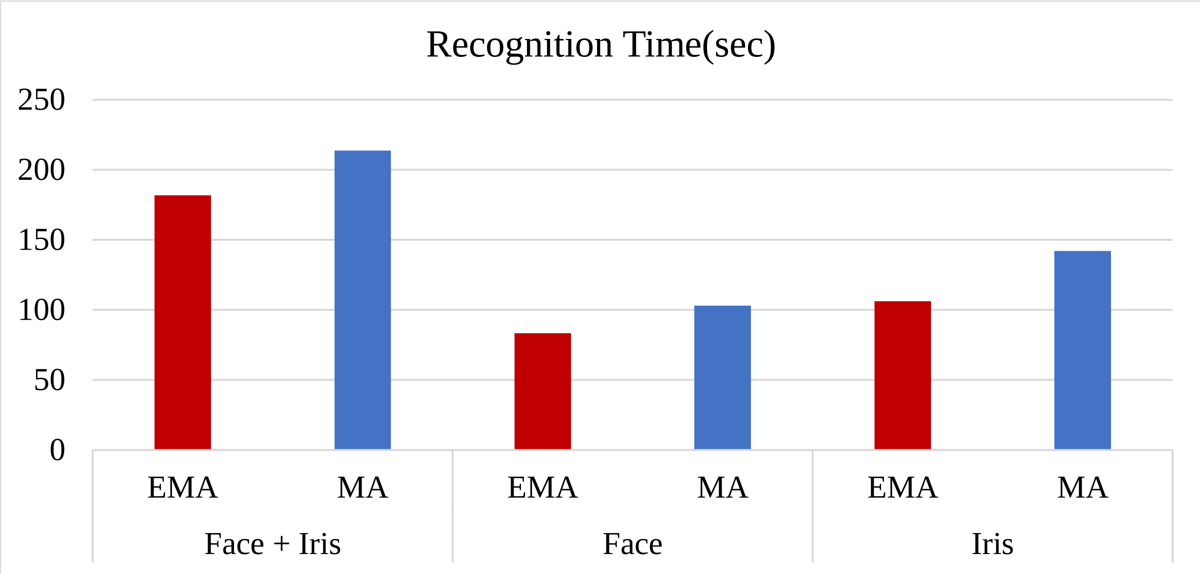

Fig. 5 Comparison of Mayfly Algorithm and Enhanced Mayfly Algorithm with roulette wheel selection at 0.76 threshold value (Recognition Time)

Table 1 and 2 shows a combined result of Enhanced Mayfly Algorithm (EMA) using roulette wheel selection and conventional Mayfly Algorithm (MA) using Random selection at the threshold value of 0.76 with respect to all matrices at different modalities.

All result obtained in the Table 1 and 2 presume that enhanced Mayfly algorithm (EMA) model has the lowest recognition time compared with the corresponding Mayfly algorithm (MA) model irrespective of the threshold value at different modalities. Likewise, Recognition Accuracy, False Rejection Rate and False Acceptance Rate, Mayfly algorithm (MA), and enhanced Mayfly algorithm (EMA) model were compared at a 0.76 threshold value, and it was discovered that the enhanced Mayfly algorithm (EMA) model has a better performance in accuracy, false acceptance rate and false rejection rate than Mayfly algorithm (MA) model as enumerated in Table 1 and 2. Enhanced Mayfly Algorithm (EMA) and Mayfly algorithm (MA) gave recognition accuracy of 97.36% and 95.18% with fused (face-iris), 93.42% and 92.11% accuracy with iris modality, and 93.86% and 91.67% accuracy with Face modality at a threshold of 0.76 respectively.

In Force Acceptance Rate, enhanced Mayfly algorithm (EMA) and Mayfly algorithm (MA) produced false acceptance rates of 1.79% and 3.51% with fused (face-iris), 5.26% and 7.02% FAR with iris modality, and 5.36% and 7.02% FAR with Face modality at a threshold of 0.76 respectively.

Similarly, the enhanced Mayfly algorithm (EMA) and Mayfly algorithm (MA) got false rejection rates of 2.92% and 5.26% with fused (face-iris), 7.02% and 8.19% FRR with iris modality, and 6.43% and 8.77% FRR with Face modality at a threshold of 0.76 respectively.

Considering recognition time, the enhanced Mayfly algorithm (EMA) and Mayfly algorithm (MA) generated recognition times of 181.52s and 213.75s with fused (face-iris), 105.98s and 142.00s recognition time with iris modality, and 83.20s and 103.07s recognition time with Face modality at a threshold of 0.76 respectively.

Figures 2,3,4 and 5 depict a comparison of the mayfly algorithm and the enhanced mayfly algorithm at a 0.76 threshold value with respect to recognition accuracy, recognition time, force acceptance rate, and force rejection rate respectively, which clearly show the superior performance of enhanced mayfly algorithm with roulette wheel selection over conventional Mayfly algorithm.

V. CONCLUSION

In this study, roulette wheel selection was used as a replacement for random selection used in the conventional Mayfly algorithm in other to tackle the limitation associated with the Mayfly algorithm. The experimental results obtained using the recognition system revealed that the fused face - iris using the enhanced Mayfly algorithm (EMA) technique gave 97.36% in terms of recognition accuracy, 1.79% false acceptance rate, 2.92% false rejection rate, and 181.52s recognition time compared with fused face - iris modality which gave 95.18% in terms of recognition accuracy, 3.51% false acceptance rate, 5.26% false rejection rate, and 213.75s recognition time. In view of this, an automated bi-modal recognition system based on fused iris and face (that is, both face and iris), would produce a more reliable accurate, and secure bi-modal recognition system on any repository system as a result of its high accuracy.

It is therefore concluded that the developed enhanced Mayfly algorithm (EMA) technique has ensured optimal computational efficiency in terms of its accuracy and time. And it can be inferred from the experimental result that the positive effect of the Roulette Wheel Selection procedure compared to Random Selection used in traditional or conventional Mayfly algorithm.

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