PHYSICAL FATIGUE ASSESSMENT FOR INTRASTATE BUS DRIVER

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ABSTRACT

Fatigue is considered a psychological or mental fatigue type characterized by subjective feelings of a disinclination to continue driving, drowsiness, fatigue, and deduction motivation. Bus drivers in Malaysia have been facing physical fatigue from driving for many years. Therefore, investigating the psychophysiological factor that related to fatigue could improve understanding and management for fatigue in the transport industry. Physical factors are divided by two parts that is upper and lower body. The objective of this study is to identify the cause, determine the level and analyze the physical fatigue on bus driver. There were two methods applied in this study, which were Modified Nordic Questionnaires and surface Electromyography (sEMG) the objective measurement. Results from sEMG showed neck and upper back muscle groups leads to fatigue as the muscle is running out of energy based from the graph. Through the sEMG data, it can determine the level of physical fatigue on bus driver and analyze the physical fatigue. Findings of this study from the questionnaire data analysis using the Statistical Package Social Science software, it is proved that physical fatigue really occurred to the intrastate bus driver. Results also showed significant correlation relationship between physical and mental.

Keywords: physical fatigue, bus driver, human performance.

INTRODUCTION

Fatigue is a common symptom experienced in the population. In many cases, fatigue is the result of mental illness or medical care, however many people experienced fatigue because of the situational factors or lifestyle such as lack of sleep, and stress. Evaluation of community based on epidemiological study of fatigue found that short duration of fatigue for example, less than 1 month in duration occur in approximately 9.75% -33% of the general population, with most estimates from 15% -25%. It is apparent that short term fatigue is a universal symptom experienced by a significant percentage of the population (Jason, Evans, Brown, & Porter, 2010).

Medically, fatigue has no specific symptom, which means that it has many possible causes. Physical fatigue refers to the use of the muscles that moves extremities, torso, digits, or head. However, it can also involved isometric muscle contraction or reduced ability to respond in a more microscopic level. Muscle fatigue, is the temporary physical inability of a muscle to perform optimally. The onset of muscle fatigue during physical activity is gradual, and depends upon an individual's level of physical fitness, and also upon other factors, such as sleep deprivation and overall health. It can be reversed by rest (Hirshkowitz, 2013). Fatigue and sleep deprivation have been identified as one of the major causes for the road accidents (Brown, 1994; Hakkanen and Summala, 2000; Sagberg, 1999; Taylor and Dorn, 2006). Physical fatigue or muscle fatigue often occur to bus drivers. In this study, most low floor bus drivers will develop early signs of physical fatigue. Ignorance will lead to permanent injury and other side effects such as low back pain. There are many caused that direct to this problem. For example, one of the important cause are the bus driver driving hours that are too long. Bus driver will not get enough rest and energy to continue driving which would affect the safety of the passengers, other road users and the driver itself. Therefore, this research need to be conducted to identify the causes, the level, and the effects of physical fatigue.

LITERATURE REVIEW

Fatigue

Fatigue are defined as a feeling of strain or exhaustion, often in both medical and psychiatric disorders, and may have physical, physiological, and psychological causes. In many cases of fatigue the cause is unknown. As reviewed by Rosenthal et al, (2008), over exertion, deconditioning, viral illness, upper respiratory tract infection, anaemia, lung disease, medications, cancer, and depression are the common causes of fatigue. Fatigue can be classified as secondary, physiologic, or chronic. Medical conditions lasting between one to six months can cause secondary fatigue. Extremes or imbalances in physical activity, sleep, diet, or other nonmedical tasks reverse with rest is characterized as physiologic while fatigue persisting for more than six months not relieved by rest is characterized as chronic fatigue (Rupp, 2013).

Factors of fatigue

Fatigue among drivers can be caused by two sources (Oron-Gilad & Hancock, 2005); (i) the driver’s
Driver fatigue

Fatigue in the context of driving is considered a psychological or mental type of fatigue that is characterized by subjective feelings of a reluctance to continue driving, sleepiness, weariness and decreased drivers motivation. Subjective sleepiness, a symptom of fatigue is defined by the feelings and physical symptoms related to the desire or need for sleep, like yawning, head nodding and drooping eye, during this period of transition between wakefulness and sleep (May, 2011b).

Physiologically, fatigue will lead to changes in brain activity and a reduction in heart rate and eye movements. Driver fatigue will lead result in cognitive and psychomotor performance vision such as increased reaction time and weaving, which can cause accidents and crashes. Unfortunately, due to variability in susceptibility to driver fatigue and how fatigue symptoms vary between individuals, there are no specific numbers or standard sizes when trying to actually define the fatigue (May, 2011a).

Driver fatigue is a safety issue of special concern in the bus transportation industry. Most mileage was consolidated during the long journey and, like many vehicles run at night, drivers frequently work irregular schedules. Because of their high annual mileage exposure and other factors, the risk of bus drivers involved in a crash related fatigue is much greater than non commercial drivers (Ann L. Barron, 2004). For a bus company, this risk may ultimately result in loss of revenues, expenses and criminal liability suits, administrative costs, loss of customer and public confidence, lack of drivers and vehicles, workers compensation, fines for employees who exceed the limits on home services, as well as increasing the rate of insurance. As a result, the bus operators are now forced to recognize fatigue and, more importantly, the driver fatigue as a major safety issue (Ann L. Barron, 2004).

Jagannath & Balasubramanian (2014), experienced that fatigue decreases an individuals ability to operate vehicles safely and reduces situation alertness. There are many factors that can cause the driver to be fatigued. It is resulting from the complex interaction of various factors (Kecklund and Akerstedt, 1993; Young et al., 2006) of which mainly:

i. Environmental factors such as road surface irregularities, low density traffic, time of day, rain, fog,

ii. Biological factors such as inadequate sleep, circadian rhythms, health, age,

iii. Socio-economical activities such as long work shifts, increased work load, alcohol, drugs,

iv. Vehicle factors such as noise, vibration and postural stress that are created by the vehicle itself, poor suspension, seat and vehicle design, demands on both physical and mental processes.

There are also multiple causes to driver fatigue studied by May (2011b), where environmental factors such as trip duration, time of day, and weather or roadway conditions may affect fatigue. It is considered to be fatigue related activities. The quality and quantity of sleep will also affect driver fatigue. It is considered to be sleep-related fatigue and also known as "drowsy driving". This task related and sleep related driver fatigue can interact and compound feelings of fatigue and subsequent decreasing the performance of drivers.

Task related causes of fatigue are task demands, duration of the trip, and monotony of the environment while sleep related causes are circadian rhythms (time of day), sleep quality, sleep quantity, and duration of wakefulness significantly affect driving performance.

Driver fatigue is a risk for any potential drivers susceptible, and it is dangerous because drivers do not see this as a hazardous situation and often do not realize how sleepy or fatigued they are (Reyner and Horne, 1998a).

Driver fatigue in the city

Based on previous studies, the current survey investigates the features of driver fatigue incidents (accidents, near accidents and unintentional events drifting-out-of-lane) that occurred in the city. The results show same patterns in the previous survey, a trip incidents tending to be short, and prior sleep loss and late night driving features as factors. Work trip feature strongly in the city fatigue incident trips and work is also a common reason for sleep loss before a fatigue incident happened. Consistent with the high representation of work trip, there are peaks hours during incident happened at travel times. Shiftworkers are prominent among the scenarios involved driver fatigue. Social trip also features among fatigue incident trips but is likely to be more difficult to meet with countermeasures (Fell & Black, 1997).

Fell & Black, (1997) studies also indicated that the following issues are examined: evidence about the prevalence and proportion of driver fatigue incidents in the city, main characteristics of driver fatigue incidents in the city, and differences from those reported by people living in more rural areas.
For conclusion based on the research of Fell & Black (1997), driver fatigue is definitely a major problem in the city. Accidents cannot be avoided whether on short trips, close to destinations, characterized by prior sleep loss, with peaks at night and at commuter times.

Raanaas & Anderson (2008), carried out a questionnaire survey with the taxi drivers in Norway to determine the prevalence of musculoskeletal pain and identify factors related to the work that is likely to increase the risk of neck, shoulder, or lower back pain. Nearly 1,500 taxi drivers across the country are selected to form the subject pool. One year prevalence musculoskeletal pain (MSP) was assessed with the Nordic Musculoskeletal Questionnaire (NMQ), and factors related to work with a questionnaire designed for the purpose.

The response included 929 of the drivers contacted. The results revealed that taxi drivers have a high risk of musculoskeletal problems compared to a Norwegian reference population. When workload and lifestyle factors were studied simultaneously, independent risk factors for the MSP are identified as driving hours per shift and per week, sleeping in the car during rest breaks, experience of violence, body mass index (BMI), unhealthy eating habits and little physical exercise. Significant demographic variables were gender and ethnic origin; female drivers and non-western immigrants being at higher risk. In addition, employed drivers had higher risk for MSP than the owner of the taxi.

Table-1. Cumulative 12 months pain prevalence (%) by gender. (Raanaas & Anderson, 2008).

<table>
<thead>
<tr>
<th></th>
<th>Women</th>
<th>Men</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample age: 10-60</td>
<td>Reference group age:</td>
<td>Sample age: 10-60</td>
</tr>
<tr>
<td></td>
<td>n=120</td>
<td>20-72</td>
<td>n=703</td>
</tr>
<tr>
<td>Neck</td>
<td>70.8</td>
<td>57.6</td>
<td>55.6</td>
</tr>
<tr>
<td>Shoulder</td>
<td>65.8</td>
<td>56.2</td>
<td>50.1</td>
</tr>
<tr>
<td>Low back</td>
<td>65.8</td>
<td>54.7</td>
<td>50.5</td>
</tr>
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</table>

Table-2.1 shows the example of a table for cumulative one year duration of pain prevalence by gender. It is reported for neck, shoulder and low back pain with a Norwegian reference population. This study sample only included 14.3% women drivers, compared with 50% women in reference population. The pain prevalence in the neck, shoulder and low back pain for both male and female taxi drivers exceeded the MSP prevalence in the reference population, independent of age.

**METHODOLOGY**

**Questionnaire**

This method is intended to obtain practical data which the actual situation occurred. The method is performed in a single stage which a detailed study in which a set of questionnaires were prepared and distributed to train drivers in hub around Kuala Lumpur and the Klang Valley. The results of the questionnaire act as a basis to fulfill the objectives of this study. The questionnaire used is a question of the Nordic questionnaire for musculoskeletal symptoms. There are 5 sections and 64 questions in this questionnaire. Part A is the demographics of the respondents. Part B is the schedule and the break time of the driver. Part C is the driver comfort. Part D based on level of drivers fatigue and lastly Part E the muscle of the drivers.

**Modified nordic questionnaires**

Standardisation is necessary to study and recording of musculoskeletal symptoms. Otherwise it is difficult to compare the results from previous studies. Considering this, it is the main reason for a Nordic group to start developing standardized questionnaires for the assessment of musculoskeletal symptoms. Even a small degree of standardization is considered useful. A major part of most questionnaires used in previous studies could have been easily comparable, but the individual questions often differed in trivial details from study to study and therefore impeded the comparison of the results. This is a sign that the knowledge about musculoskeletal symptoms are not enough to allow an advanced level of standardization. The questionnaires used in this study had been modified to match the related questions.

A questionnaire was distributed to the driver to complete. Through this questionnaire, it can capture the problem faced by the bus driver and make the analysis related to the background and health status of the respondent from the demographic variables.

**Surface electromyography**

The objective measurement for this study was done for the surface electromyographic where a 16 channel sEMG machine Megawin ME6000 were used. Raw sEM signals were filtered using 15-450 Hz band pass filter by the Megawin software. Five parts of muscle group were chosen based on preliminary studies for implication in driving, intensity of signal generated and accessibility of muscle for electrode application. The muscle groups are sternocleidomastoid (S), latissimus dorsi medial (LDM), erector spinae (ES), gastrocnemius and extensor carpi radialis (ECR). Before the measurement electrodes are being placed to the respondent, the required placement site where identified, shaved, and cleaned with alcohol to avoid impedance mismatch and movement artifacts such as hair that will affect the data. The filtered signals were windowed for every one hour each at an interval of twenty minutes and then archived for subsequent analysis.

Seven male participants volunteered for the EMG measurement. All participants had a Competent Driving License (CDL) and Vocational Driving License (VDL) respectively. The drivers had been brief and explained about the study protocol before the EMG was being placed. A written informed consent letter was taken from
volunteers to enroll as participants in the study. Only Putrajaya Central hub that undergone the EMG measurement.

The light intensity is varied at the distance from the eyes of the beholder. It is safe to say that the light intensity is decreased as the distance increase. The light intensity also the influence of the air absorb by the surroundings, thus the intensity becomes less appealing as the distance increase (Yang, 2010). Firefly algorithm was followed three idealize rules, 1) Fireflies are attracted toward each other regardless of gender. 2) The attractiveness of the fireflies is correlated with the brightness of the fireflies, thus the less attractive firefly will move forward to the more attractive firefly. 3) The attractiveness of fireflies is depend on the objective function (Yang, 2010).

**Structure of firefly algorithm**

In firefly algorithm, there are two important variables, which is the light intensity and attractiveness. Firefly is attracted toward the other firefly that has brighter flash than itself. The attractiveness is depended with the light intensity.

The light intensity thus attractiveness is inversely proportional with the particular distance \( r \) from the light source. Thus the light and attractiveness is decrease as the distance increase.

\[
I(r) = I_0 e^{-\gamma r^2}
\]

\( I \) = light intensity,  
\( I_0 \) = light intensity at initial or original light intensity,  
\( \gamma \) = the light absorption coefficient  
\( r \) = distance between firefly \( i \) and \( j \)

**Figure-1.** Pseudo code for firefly algorithm (Yang, 2010).

Attractiveness is proportionally to the light intensity seen by the another fireflies, thus attractiveness is \( \beta \)

\[
\beta = \beta_0 e^{-\gamma r^2}
\]

\( \beta_0 \) = Attractiveness at \( r = 0 \)

The distance between two fireflies can define using Cartesian distance

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

Firefly \( i \) is attracted toward the more attractive firefly \( j \), the movement is defined as

\[
\Delta x_i = \beta_0 e^{-\gamma r_{ij}^2} (x_j^t - x_i^t) + \alpha \xi_i, \quad x_i^{t+1} + \Delta x_i
\]

In equation (4), the first term is for attraction, \( \gamma \) is the limitation when the value is tend to zero or too large. If \( \gamma \) approaching zero \( (\gamma \rightarrow 0) \), the attractiveness and brightness become constant, \( \beta = \beta_0 \). In another word, a firefly can be seen in any position, easy to complete global search. If the \( \gamma \) is nearing infinity or too large \( (\gamma \rightarrow \infty) \), the attractiveness and brightness become decrease. The firefly movements become random. The implementation of firefly algorithm can be done in these two asymptotic behaviors. While the second the term is for randomization, as \( \alpha \) is the randomize parameter. The \( \xi_i \) can be replace by ran -1/2 which is ran is random number generated from 0 to 1.

**Variation of firefly algorithm**

Firefly algorithm is widely use to solve many problems, such as solving the economic emissions load dispatch problem (Apostolopoulos and Vlachos, 2011), multilevel image thresholding selection (Horng & Jiang 2010), finding optimal test sequence generation (Srivatsava, Mallikarjun and Yang, 2013), solving travelling salesman problem (Kumbharana and Pandey, 2013), vector quantization for image compression (Horng, 2012) and object tracking (Gao et al., 2013).

Despite that firefly algorithm is widely used for solving problem, stand art firefly algorithm also have some coming in term of trapping into several local optima when solving complex problem (Farook and Raju, 2013), (Yu, Yang and Su, 2013). There is disadvantages of using of single method only, this is because it will be overly restrictive for high dimensional and nonlinear problem. Thus, some modification and hybridization is suggested to overcome the shortcoming of single method (Abdullah et al., 2012).

**Modified firefly algorithm**

In stand art firefly algorithm, global best is the current best solution of firefly or known as the firefly that hold the highest light intensity or attractiveness. This firefly will move randomly to find the next best firefly for the next iteration. Since the firefly is move randomly, the attractiveness will be lose in certain distance from the others fireflies. Thus this will lead to the loose of performance in that particular iteration (Yang, 2010), (Tilahun and Ong, 2012), (Hassanzadeh and Meybodi, 2012).

In paper of (Tilahun and Ong, 2012) propose that, instead of the firefly move in random behavior, but in the proper manner. The firefly is only move to the direction if only there is improvement of brightness. The author (Tilahun and Ong, 2012) propose modification is by generate unit vector, then to determine the movement of firefly is by direction that leads toward the increases of brightness firefly. If there is none; the current brightest firefly will stay in the current position. As for (Wang et al., 2012), in the paper also done some modification toward firefly algorithm for improvement. First is to add Lévy flight for improvement in term of localized searching for closer solution. In paper written by (Yu et al., 2013),

![Image](image-url)
Olamaei, Moradi and Kaboodi, 2013), (Farahani et al., 2011) is to proposed to use adaptive formulation for randomization value $\alpha$. This is because when the value of $\alpha$ is large it is better for firefly to explore unknown place while small value of $\alpha$ will make firefly for local search. In (Farahani et al., 2011) the author also propose the movement of firefly that is change from random movement to direct movement. This is happen when there is no brighter firefly from the particular firefly, then firefly will move randomly. To avoid this, the author propose that the random movement is change to direct movement and the firefly will move toward the best solution in that iteration. This will make firefly in the better position for next iteration and help to achieve to near global best.

**Hybrid firefly algorithm**

Solving problem with only one metaheuristic is rather restrictive. This is because the single metaheuristic is hard to reach the optimal solution within reasonable time. Thus by combining with other metaheuristic or called hybridization will help with the high dimensional and nonlinear problems. Hybridize metaheuristic also can provide a more efficient behavior and a higher flexibility when dealing with real-world and large scale problems (Abdullah et al., 2012), (El-Sawy, Zaki and Rizk-Allah, 2012), (Rizk-Allah, Zaki and El-Sawy, 2013).

In this paper, the author (Farahani et al., 2012) propose of using Genetic Algorithm hybridize with Firefly Algorithm. This is because of the basic firefly algorithm weakens is in global optima. Thus, by using genetic algorithm which is more suitable for search globally, it will find better solution. By completing this, firefly algorithm will be used the solution for local search.

There is hybridization done after completing between two or more algorithms paralleled. In the paper by (El-Sawy, Zaki and Rizk-Allah, 2012), the Ant Colony Optimization and Firefly algorithm is done parallel and the result is sorted base on the constrain violation by descending order of the feasibility rule. The rules are grouped based on, the feasible solution preferable compare to others infeasible solution, or if there are two feasible solution, which have better objective function is preferable, and last is if there is none feasible solution, which have small constrain of violation is preferable.

In the hybrid firefly algorithm introduce by (Abdullah et al., 2012) is combination between firefly algorithm and differential evolution. The population of firefly will be produce into two group, one is in the with the potential fitness values, and will proceed to calculate the distance between solution using Euclidean distance and attractiveness. The others sub population which is contains of less significant fitness value will used evolutionary operation of differential evolution. This will produce offspring solution, if these offspring solutions have better fitness values, it will be replace the original solution. If not, the original solution will be remains till next iteration.

**Application of firefly algorithm**

Firefly algorithm is vastly used for solving engineering problem and optimization. Even only stand art firefly apply for solving problem can produce superior result, but some modification or hybridization is done for convenient of application to apply firefly algorithm to solving multi-dimensional and nonlinear problem.

**Routing problem**

Firefly algorithm is adapt from the behavior of firefly that attracted to the more attractive firefly (Yang, 2010). Thus, by using the characteristic of firefly, researcher apply firefly algorithm to find the shortest path or route for vehicle, bus or salesman. Below is example of application of firefly algorithm to find the shortest or optimum route for the problem. There are many variable and conditions that the researcher to deal in order to solve the problems.

Travelling salesman problem is to find the shortest distance in tour city that visited once. The salesman have to find the shortest distant that can cover all the stops, visited once and return to the starting point. In paper by (Jati, Manurung and Suyanto, 2013), the author use evolutionary discrete firefly algorithm (EDFA) with some modification from the original. In the original EDFA, the firefly did not have direction of movement. Thus, movement in new EDFA is adapt from the evolution strategies (ES), which is used the inversion mutation. In the paper, the author also discuss about discrete firefly algorithm (DFA). The movement of firefly in DFA is different from EDFA. The total number of firefly in EDFA is constant per generation. While the total number of firefly in DFA is changing base on total number of firefly with best objective function.

Some modification done by (Kumbharana and Pandey, 2013) in his paper to adapt TSP with FFA which are initial solution, distance function and movement. In initial solution, the pseudo code by Yang describe that the fireflies is scattered over the search space. But with good solution among random solutions, it will make immediate advance toward better solution. By using this method, it will make faster to find local optima. As for distance function, instead of using Cartesian distance, the author uses Hamming’s distance and numbers of swapping required being same with the next solution. For the movement, the firefly is represented in form of permutation matrices, and then inverse it to preserve the previous path formed.

Firefly algorithm also has been use in the research of vehicle routing problem. Vehicle routing is a problem to find the set of route for the fleet of vehicles to serve the number of stops. The number of stops is deterministic, when there is no demand exceed the capacity of the vehicle, it is the standards vehicle routing problem. The VRP can be extend into many constrains such as time window, mix pick up (backhauls) and deliveries (linehauls) (Breedam, 2001).

There are many variation of vehicle routing problems, one of it is Vehicle routing problem with time
windows (VRPTW). VRPTW is aim for to find route to the all vehicle to such that all the customer will be serve within the respective time windows. In practice, the customers and the carrier companies have difference concerns. For the customers, is to receive the deliveries on time, while the carries company is to delivers the goods to the different customers efficiently while be able to cut cost and save the time (Tas et al., 2013). This paper of (Pan et al., 2013), the authors adopt the VRPTW coding from CVRP. The modification of infeasible solution is done, so that only the effective solution that have the requirement of value will be kept.

Finding path by using firefly algorithm also is not restricted for road vehicle, firefly algorithm also had applied for finding route of uninhabited combat air vehicle (UCAV). There are constrain of UCAV that should not be over looked. The route planning for UCAV should include the terrain, data, threat information, fuel and time (Wang et al., 2012). Thus in the paper, the author (Wang et al., 2012) do improvement of FA algorithm, so that it able to search the most optimal route with multi constrains.

**Image processing**

Firefly algorithm in image processing would also is not new, there are bunch of research base on image processing using firefly algorithm such as multilevel image thresholding selection (Horng and Jiang, 2010), active contour model for medical image segmentation (Sahoo and Chandra, 2013) and vector quantization using the firefly algorithm for image compression (Horng, 2012).

The example of how to include a figure in one column is shown in Figure-2.

![Figure-2. Variant of slump with laterite content of laterized concrete.](image_url)

In paper of (Horng, 2012), had used firefly algorithm to solve vector quantization by hybridize the firefly algorithm with Linde–Buzo–Gray, (FFA-LBG). LBG is a scalar quantization that used for input vectors for determining the codebook. In FFA-LBG, LBG is put at the first part of the initial solutions. The author conclude that FFA-LBG method is achievable same par with the PSO-LBG and QPSO-LBG with the less the computation time.

In image processing, there is one segment for image tracking using video sequence. Object tracking is one of the research that is vastly studied into real world application such as surveillance, vision based control and robotics. On the other hand, video sequencing for object tracking still a challenging topic for researches due to large amount of data used and high specification for real time computation (Gao et al., 2013). The authors state that, to overcome problems in the object tracking the researcher used the varieties of methods and algorithms. One of the optimization algorithm that is doing well is meanshift. From this research, the authors conclude that the firefly algorithm is indeed superior compare to particle filter, particle swarm optimization and meanshift in tracking object. The result is compare in four different method and shows that firefly algorithm out perform in term of speed and accuracy.

Table-2 shows an example of a table. If the table is large, you can put the table in a single column format.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2 3</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>4 5</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>2 9</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Firefly algorithm is considering new algorithm in the swarm intelligence family. Despite that, the usage of the firefly algorithm in the various types of problem shows that the anticipation from the researcher to use this algorithm. This algorithm already proves that it is superior compared to the previous introduce swarm intelligence from the research done before. Even though the firefly...
algorithm has proven to be superior compared to the previous swarm intelligence, some modification can be done to improve the local search a well as global search to ensure the solution obtains is the optimum and not premature solution.

Firefly algorithm also suitable be used for the high dimensional and nonlinear problems. The downside of it is the single that the single metaheuristic is hard to reach the optimal solution within a reasonable time. Thus, by combining the metaheuristic will help to overcome the shortcoming of the single metaheuristic algorithm.

In the future work, the researcher should tackle firefly in more various types of problem such as find optimum route for new build trains rails route which is have multiple constrains such as to preserve the nature maximum as possible and multi tracking for object tracking

REFERENCES


