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The Application of Firefly Algorithm in An Adaptive Emergency Evacuation Centre Management (AEECM) for dynamic relocation of flood victims

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Abstract. Flood evacuation centre is defined as a temporary location or area of people from disaster particularly flood as a rescue or precautionary measure. Gazetted evacuation centres are normally located at secure places which have small chances from being drowned by flood. However, due to extreme flood several evacuation centres in Kelantan were unexpectedly drowned. Currently, there is no study done on proposing a decision support aid to reallocate victims and resources of the evacuation centre when the situation getting worsens. Therefore, this study proposes a decision aid model to be utilized in realizing an adaptive emergency evacuation centre management system. This study undergoes two main phases; development of algorithm and models, and development of a web-based and mobile app. The proposed model operates using Firefly multi-objective optimization algorithm that creates an optimal schedule for the relocation of victims and resources for an evacuation centre. The proposed decision aid model and the adaptive system can be applied in supporting the National Security Council's respond mechanisms for handling disaster management level II (State level) especially in providing better management of the flood evacuating centres.

Keywords: flood, evacuation centre, optimization, firefly algorithm

INTRODUCTION

In the past decade, Malaysia has experienced a number of major floods. In December 2006, January 2007 and January 2015, Malaysia was hit with the worst flood in 100 years. The flood caused more than 100,000 people to be evacuated in the state of Johor alone in January 2007, with the total cost of the damage in the country estimated to be RM1.5 billion. In November 2010, the north Malaysian were hit with a series of floods concentrated in the Malaysian states of Kedah and Perlis. The floods involved around 50,000 people evacuated and left at least four people dead [1]. The vast increasing numbers of the lost from flood enforces the government to take proactive steps in dealing with flood problems such as setting up supervisory bodies, implementing flood mitigation programmes, implementing non-structural steps with the setting up of flood forecasting and warning systems for the flood prone area.

Nevertheless, the most important flood management focused on the immediate evacuation for the victims. The evacuation and relocation of flood victims involves a lot of capital. As informed by the Minister in the Prime Minister Department in March 2011, almost USD 21.12 million was spend in for 89,000 flood victims in five states effected by the disaster and it was estimated that 53 percent of that amount was spent on relocation of the victims,

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which also includes food and other daily necessities. At the moment, there are 5,156 evacuation centres nationwide have been identified which could accommodate up to 1.4 million flood victims with 28,000 disaster relief personnel from various agencies as well as 12,500 volunteers from NGOs on standby. These evacuation centres have been setup to accommodate flood victims which increasing yearly.

Currently, there is no research yet done to provide solution on reallocating victims and resources when the evacuation is almost drowned. Therefore, this research proposes an Adaptive Emergency Evacuation Centre Management (AEECM) which is capable of providing a decision support capabilities to provide solution for relocation of victims and resources to other evacuation centres when these centres are drowned. The proposed solution will provide information on the quantity of victims and resources that are required to be transported to the new evacuation centres.

This paper presented An Adaptive Emergency Evacuation Centre Management (AEECM) as a decision support in relocating flood victims. Section 2 discussed evacuation center management and the issues, while Firefly Algorithm is covered in Section 3. Methodology of designing and devoping the model is covered in Section 4, while concluding remarks are covered in Section 5.

EVACUATION CENTRE MANAGEMENT

The flood evacuation centres are managed by the Department of Social Welfare (*Jabatan Kebajikan Masyarakat, JKM*). This department works closely with a number of governmental and non-governmental agencies to provide necessary steps to ensure safety and comfort in every evacuation centre. These individuals are the backbone of the flood evacuation centres and often face difficult decision making problems. Despite immediate actions have been taken by the Department of Social Welfare to manage all victims at the evacuation centres, the authority still fall short to manage the flux of victims.

Due to the large number and urgency of managing the flood victims, the authority is facing some problems to manage all victims effectively. The volunteers and officers cannot resolve all of the problems faced by victims who have been living in evacuation centres for longer period of time due to the lack of supply, funding, or access. Even though these people usually have clear instructions about how to act, they often have difficulties in making appropriate decisions, due to a combination of factors, including time pressure and heavy emotions. In the recent 2015 flood tragedy, several flood evacuation centres in Kuala Krai were drowned. For example SMK Manek Urai was drowned where it previously held 500 evacuees [2].

Despite the information that the rescuing team and evacuation centre staff have from the e-banjir portal on the evacuation centre for example on the current water level, number of victims at each evacuation centre, quantity of flood supply and others, the rescuing team was late in making decision to reallocate the victims to other safer evacuation centres. The flood already reached the third floor of the school building before they started to move the victims to other centres. Therefore, this has risen to the needs of having a decision support aid that is able to provide solution to help the evacuation centres staff to make quick and accurate decision to reallocate the trapped victims and their resources to the safest evacuation centres. Early interview with an officer of Kedah State, Department of Social Welfare, Rusdi Ishak [3], also supported the same claim.

There are many issues that have to be considered while planning and managing evacuation centres during flood disaster. Among the issues that is closely related with evacuation centres is on resource coordination and distribution. Multiple demands on resources are to be expected and how these demands will be addressed and prioritised has to be decided. Where gaps are identified, mutual aid should be considered and arrangements of victims to other evacuation centres with adequate resources should be put into place [4].

Zhu [5] proposed a resource allocation model that is aimed at determining the location of reserve depots and the amount and type of resources to be stored. It is modelled based on discrete scenarios that is divided into two; local government and national. Their optimization focuses on the commodities inventory holding and transportation cost. A more recent work was discussed in [6] that proposed a model that identifies the optimal number, location and inventory level of warehouses around the world in the occurrence of a disaster. The model considers uncertainties on product quality, availability and production capacity in affected areas.

FIREFLY ALGORITHM

Firefly algorithm (FA) is considered as a new member in swarm-based community. It is a metaheuristic optimization algorithm that was developed by Xin-She Yang in 2007 at the Cambridge University. It operates based on the nature of fireflies which produce short and rhythmic flashes. The flashing light is generated by the bioluminescence process. Its function is to attract mates or prey. The firefly flashing characteristics have three idealized rules [7] :

- All fireflies are unisex and one firefly attracts to another.
- Attractiveness is directly proportional to their brightness, hence, the brighter firefly will attract the less bright ones.
- The firefly brightness is determined by the search space of an objective function

There are two important issues in the FA; light intensity and the attractiveness. Light intensity, I, at a specific location, x, of one firefly can be determined by an objective function, $F(x)$. The objective function can be maximized or minimized optimization problems. On the other hand, the β is the attractiveness of a firefly. It changes based on the distance between two fireflies.

Firefly Algorithm has been implemented in various domains such as speech recognition [8], image segmentation [9] and [10], resource allocation [11], web service composition [12], data classification [13] and anomaly detection [14]. These existing works have shown that the adaption or adoption of Firefly Algorithm in the selected areas is a success. Hence, this study proposes the adaption of Firefly Algorithm in scheduling the allocation of victims and/or resources for an evacuation center or between the centers.

THE PROPOSED MODEL

An Adaptive Emergency Evacuation Centre Management (AEECM) is proposed as a decision support tool to provide solutions for relocation of victims and resources to other evacuation centres when the existing centres are drowned. The proposed solution will provide information on the number of victims and resources that are required to be transported to the new evacuation centres.

Three main phases involved in designing and developing AEECM which operates based on multi-objective optimization algorithm are (a) design and development of Firefly multi-objective and (b) design and development of the mobile apps and web-based of AEECM, and (c) evaluation of AEECM.

FA Development

FA is adapted in finding the best available evacuation centres to relocate the victims if the existing evacuation centre itself is predicted to be closed. Based on its strength, FA is capable of achieving the mentioned objectives. Factors to be considered in selecting new evacuation centres are distance, capasity, water level of nearby rivers, and its distance from the nearby rivers. Based on the mentioned factors and criteria, the following pseudocode is designed.

Input:

Step 1: Input the dataset that includes four variables [v1, v2, v3, v4].
Step 2: Define light absorption coefficient γ, where γ=1.0
Step 3: Define initial attractiveness $\beta_0 = 1$
Step 4: Determine the Max Generation.
Step 5: Determined the Capacity.
Step 6: Determined the number of fireflies which equal10% from the number of records in dataset.
Step 7: Determine the number of initial solution which is equal the number of fireflies.

Process:

Step 8: The solutions are represented in binary form [0 or 1], where the dimension of one solution equal the number of records in dataset.
Step 9: Generated the solutions are undertaken in two ways:
Step 9.1: If the variable v1 in one record pass the capacity, it will take it as one solution by assigning 1 in solution.
Step 9.2: If the v1 in one record less than the capacity, then, the solution will generated randomly that take more than one record in one solution.
Step 9.3: Check the generated solution must pass the constrain which is the summation of v1 of all record in one solution pass the capacity value.
Step 10: Calculated the initial utility function for each solution. Utility function Fi= summation of v1 of all record+ summation of v2 of all record+ summation of v3 of all record+ summation of v4 of all record
Step 11: Assign the utility value to each firefly as initial light (I).
Step 12: Determine initial position of each firefly, which represent the solution.
Step 13: While (t < Max Generation)
Step 14: For i=1 to N (N all fireflies)
Step 15: For j=1 to N
Step 16: If (Ii>Ij) {
Step 17: Calculated the distance between two solutions using the following equation:
Step 18: Calculated the attractiveness between two solutions using the following equation:

$$\beta = \beta_0 \exp^{(-\gamma r_{ij}{}^2)}$$

Step 19: Move brighter firefly to less brighter firefly (minimization problem)

$$X^i = X^i + \beta_0 \exp^{(-\gamma r_{ij}{}^2)} * (X^j - X^i) + \text{rand} - 0.5$$

Step 20: If summation of v1 in new solution >= Capacity
Step 20.1: Calculated the utility function for new solution.
Step 20.2: Compare with old solution.
Step 20.3: Replace old solution with new solution.
Step 21: Else if summation of v1 in new solution < Capacity Does mutation for one bit random in new solution until pass Capacity.
Step 21.1: Calculated the utility function for new solution.
Step 21.2: Compare with old solution.
Step 21.3: Replace old solution with new solution.
Step 22. End For i
Step 23. End For j
Step 24. End While
Step 25. Rank the fireflies and find the current global best utility function, and best solution.

Output

Step 26. Sort the best solution based on the v1 variable.

FIGURE 1. Firefly multi-objective pseudocode

System development

This phase involved requirements gathering and development of web-based and mobile apps of AEECM. The FA with multi-objective algorithm and supporting model have been translated into Android platform using PHP and Java, as shown in Figure 2.

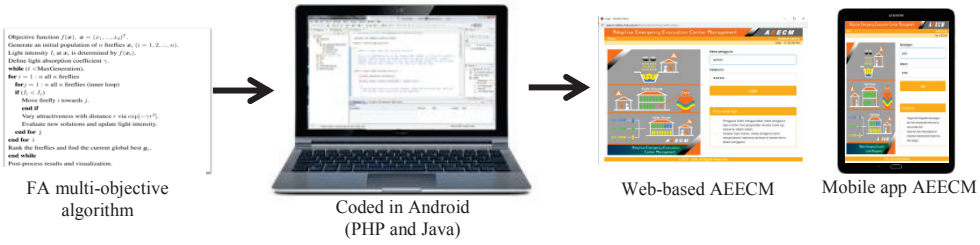
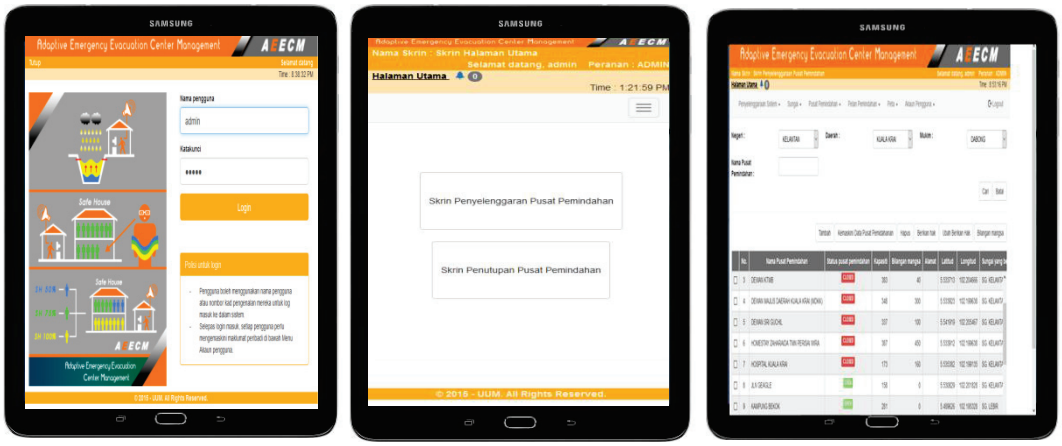


FIGURE 2. Development of mobile AEECM

AEECM is developed for authorities who are managing evacuation centers; JKM officer, rescuers, and the head of villagers. As a start, Kuala Krai, Kelantan is chosen involving 109 evacuation centers from four districts; Guchil, Mengkebang, Manek Urai, and Dabong. Interfaces of AEECM are illustrated in Figure 3. Two main functions of AEECM are maintenance of evacuation centers and closing of evacuation centers, as shown in Figure 3(b). Maintenance will be handled by JKM officers, while authority to close the evacuation center is given to the head of villagers, who is incharging the evacuation center in their area. Evacuation centers will be closed when water level

approcahing danger level. In order to close, victims need to be relocated. Status of evacuation centers can be seen in Figure 3(c).



(a) (b) (c)

FIGURE 3. Interfaces of AEECM

System Evaluation

AEECM has undergone a thorough system testing, which 38 tests cases have been constructed. For comparison purpose, AEECM which runs using FA was compared with Tabu search as depicted in Table 1.

TABLE 1. AEECM test against Tabu search

Center to evacuate	Firefly solution	Tabu Search solution
EC 20 (150 people)	EC 1 (100) EC 99 (50)	EC 1 (50) EC 34 (50) EC 44 (50)

Based on Table 1, an evacuation center with 120 victims is going to be closed. All victims need to be relocated to the other available evacuation centers. Result shows that AEECM with FA produced a better solution by relocating victims to only two evacuation centers, while Tabu Search has relocated the same victims to three evacuation centers. Result suggested by FA is more economic and less hassle in transporting the victims.

User acceptance test of AEECM will be conducted in Kuala Krai, Kelantan involving respondents among the officer of Social Welfare department (JKM), the rescuing teams, head of villagers, and the manpower of evacuation centres.

CONCLUSION

This paper proposed an Adaptive Emergency Evacuation Centre Management (AEECM) which is capable of providing a decision support capabilities to provide solution for relocation of victims and resources to other evacuation centres when these centres are drowned. The proposed solution will provide information on the quantity of victims and resources that are required to be transported to the new evacuation centres. The proposed decision aid model and the adaptive system can be applied in supporting the National Security Council's respond mechanisms for handling disaster management level II (State level) especially in providing better management of the flood evacuating centres.

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