# Building Fire Evacuation model research Based on an Improved Fruit Fly Optimization Algorithm

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**Abstract.** We take into account to find a set of rapid evacuation routes during a building fire. We construct a three-dimensional building structure of the network, an evacuation route is a sequence of movements of people away from the threat of fire, to a safe exit in the network. The fire can stress crowds, cause their competitive behaviors, lead to disorder and blocking as they pass through the nearest passages and exits. This paper provide a novel improvement fruit fly (IFOA) algorithm for the 3D route of evacuation with different node flow rate limiting characterizing. The algorithm has been proved feasible and effective after test the database.

## Introduction

In recent years, there is a growing concern over the problem of fire safety evacuation [1]. Because high-rise building has a fire spread fast, it is very difficult to evacuation and rescue. How to make the staff out of fire in the finite evacuation time, that is the important content of the building safety design.

During the last decade, the crowd evacuation modeling of research findings have the queuing model[2], continuous crowd flow [3]. Typical models are building EXODUS[4]; EXITT[5]; SIMULEX[6]. This model can not reflects the individual characteristics, interaction between individuals in disasters. For the shortest routes choose, Cova et al[7] propose a lane-based large-scale evacuation network flow model. Campos[8] provide a k-shortest path algorithm. Chen[9] provide a monophyletic fastest flow algorithm. Andreas [10] use LP and nonlinear programming. It can not reflects the influence of structure and environment on the crowd evacuation behaviors and mentality.

In this paper, we construct a three-dimensional building structure of the evacuation network, an evacuation route is a sequence of movements of people away from the threat of fire, to a safe exit in the network. The sensory of fire can stress crowds, lead to disorder and blocking as they pass through the nearest passages and exits, the further stairways and exits can be not make full use. How to optimize crowd guidance is an important problem. We provide a novel improvement fruit fly (IFOA) algorithm for the 3D path of evacuation with different node flow rate limiting. By dispersing passages capacity and evading the nearest exits, to avoid possible disorder and blocking. This work is further the extension the former work. We stress considered practical problem two main requirements: (i) The method should be improved the defects of conventional evacuation guidance. It is very fast to be used by the evacuation supervisors in real time. (ii) It should be provide effective help to be not familiar with the environment of evacuees.

We apply a graphical presentation for modelling building evacuation.The graph is the three first floors of the laboratory building on the Northeastern University. Experiments are conducted to verify the feasibility and effectiveness of our proposed approach.

The rest of the paper is organized as follows: In the next section we introduce network model of building space. In Section 3 we present the principles of basic FOA and improved FOA. In Sections 4 we apply the model to solve evacuation problem, and the experiment result analysis. We provides

conclusions and future work in Section 5.

## Network Model of Building Space

### Properties of Building Evacuation Space

Network nodes and evacuation passages propertie are defined and described as follow. The structural of system is represented as $G=(W,E)$ a network, where each area is denoted by a vertex $w \in W$ and each passage connecting areas is denoted by an arc $e \in E$. Nodes set $W=\{w_1,w_2,...,w_n\}$, and definition $w_i(ID_i,x_i,y_i,z_i,t,k_i(t),n_i(t))$, where $ID_i$ is the ith node number, $x_i,y_i,z_i$ building space the three-dimensional coordinates, respectively, $k_i(t)$ is the integrated comprehensive information of fire in anytime t, $n_i(t)$ is the number of evacuee from the source node in anytime $t$. The edges correspond different passageways and stairs. Passage set $E=\{w_1w_2,w_2w_3,...,w_iw_j,...,w_mw_n\}$.

### A Three-Dimensional Path Planning Problem Description

Path planning is to find the shortest sequence from the source nodes to the exit. The definitions are as follows:

The definition 1: any point in floor $w_i(x_i,y_i,z_i)$, if the edge $e_{w_iw_j}$ isn't intersect with any obstacles, to store the set $W_{allowde}(x_i,y_i,z_i)$.

The definition 2: the dist anceany two adjacent node $w_i,w_j$, $L_{w_iw_j}$ are shown in:

$$L_{w_iw_j}=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2+(z_i-z_j)^2} \tag{1}$$

By definition 2 we can be calculated out the distance between any two nodes.

Considering the diffusion of fire, the evacuation route $d_{w_iw_j}$ calculation formula:

$$d_{w_iw_j}=kl_{w_iw_j} \tag{2}$$

where $k$ is the integrated comprehensive information fire.

### Modeling Nomenclature

$N$    total number of evacuees. $R_l$    evacuees to choose the route, $l=1,2,...,L$

$n_{il}$    the number of people through the path $r_l$ and node $w_i$. $RC_i$ the maximum flow rate of passage $R_l$,    $RC_l=\min\{c_{ij}\mid e_{ij}\in R_l\}$ , $c_{ij}=n_{il}(t)\big/l_{ij}$

$C_i^{UB}$    the maximum crowd floe rate of node the unit time, $person/m \cdot s$

$T_{r_l}$    the time for route $r_l$, $T_{r_l}=\sum\limits_{e_{ij}\in r_l}\dfrac{d_{ij}}{v}$, $v$ the flat straight road    walking speed

$T_{w_i}$ the time for a group evacuees to go through the exit    $T_{w_i}=\begin{cases}\dfrac{n_{il}}{RC_l} & ,RC_l\le C_i^{UB}\\[2mm]\dfrac{n_{il}}{C_i^{UB}} & ,RC_l>C_i^{UB}\end{cases}$

$T_{il}$    total evacuation time any node and path, $T_{il}=T_{r_l}+\max T_{w_i}$, depending on the number of people through the node into the path

The objective function and constraints :

$$\min f_1=\sum_{i=1}^{K}\sum_{l=1}^{L}T_{il}(n_{il}) \tag{3}$$

$$s.t.\ \sum_{i=1}^{K}\sum_{l=1}^{L}n_{il}(t)=N \tag{4}$$

$$\frac{n_{il}(t)}{C_i^{U}\cdot t}\le 1 \tag{5}$$

**Improve FOA Algorithm(IFOA)**

**The Basic FOA and Applying**

The Fruit Fly Optimization Algorithm (FOA) was proposed by Pan[10]. FOA is a new swarm intelligence method based on the food finding behavior of the fruit fly[11]. The olfactory organ of fruit flies can discover the floating scents in the air. Then use its sensitive vision to find food and fly towards that direction [12].

Since FOA has been proposed, FOA has been applied in several applications, such as neural network parameters controller optimization[13,14], and the knapsack problem etc.[15].

**IFOA for the Model**

Consider to devise the fitness functions is defined as:

$$f(X) = \min\{d(X, w_j), w_j \in W_{allowed}\} \tag{6}$$

IFOA is divided into several necessary steps, The steps are:

Step 1. Initialization.Given the maximum Maxgen $K_{max}$ and sizepop. Set the lower bound $(C^{LB})$ and the upper bound $(C^{UB})$ of $C_i$.sub-swarms number $M$.Initialize fruit fly swarm location Init $X\_axis$, $j=1,2,...,n$ which represents each node data variable, $i=1,2,...,popsize$ which shows each individual fruit flies, $m=1,2,...,M$ which represents each sub-swarm.

Step 2. Randomized initial fruit fly swarm location matrix:

$$X_{i,j,m} = X\_axis_m + R(k) * rand[0,1]$$

with

$$R(k) = \left(\frac{C_i^{UB} - C_i^{LB}}{2}\right)\left(\frac{k\max - k}{k\max}\right)^\phi$$

where $\phi = 2-6$. $rand \in [0,1]$.

Step 3: The distance of food source to the initialization location is calculated as follows:

$$Dist_{ij} = X_{ij}$$

$Dist_i$ should be limited by the following rule:

$$Dist_{ij} = \begin{cases} C_i^{UB}, Dist_{ij} > C_i^{UB} \\ C_i^{LB}, Dist_{ij} < C_i^{UB} \end{cases}$$

Step 4. Find the fitness value (*smell_i*)of the individual location of fruit fly.

Step 5. Find out the fruit fly with the minimum value among each sub-swarm.

Step 6. Judge and update the fitness value of each sub-swarm.

Step7. Update the global fitness and best position $X\_axis$ among multi-swarm.

Step 8. Perform cooperative local search method by

$$X\_new = \frac{1}{M}\sum_{m=1}^{M} X\_axis_m$$

Step 9. Vision searching process. the probability of fruit flies choosing the next exit $P(w_j)$ is:

$$P(w_j) = \begin{cases} \dfrac{\varpi_1 x(j) + \varpi_2 x\_new(j)}{\sum\limits_{j\in w_{allowde}}(\varpi_1 x(j) + \varpi_2 x\_new(j))} &, j \in \{reachable\ neighbors\} \\ \\ 0 &, j \in \{unreachable\ neighbors\} \end{cases}$$

where $\varpi_1$ and $\varpi_2$ are weights, and $\varpi_1, \varpi_2 \in (0,1)$.

Step 10. If $k \geq$ Maxgen, stop the IFOA search, otherwise, go to Step 2.

**Experimental Result**

The model and IFOA algorithm were used MATLAB7.0 coding and run on the PC with 2.53GHz, and 2G memory. The initial population is 20 and 30, muti swarm number 3, $\varpi_1 = 0.4$, and the iteration $k=200,300,500.1000$. Fig. 1 fruit fly flying route, Fig. 2 (a) (b)The best fitness based on

IFOA and FOA, respectively. Further analyze the performance of the FOA and IFOA in 3D evacuation space. The average evacuation time computed by two algorithms for different number of people are drawn in Fig. 3. we are compared 200, 300, 500, 800 people evacuation time. The results show that all the people are transferred to safe exit region by time period 480$s$. The results demonstrate that the proposed model is fit for solving buildings fire evacuation problem.

We consider a graph fragment earlier presented. The evacuation routes are depicted in Fig.4.This optimum route consists of 10 nodes connection as follows: 1-7-3-11-9-15-16-20-18-21. People select different route towards the exit as time goes on. Therefore, congestion on the nearest exits is avoided.
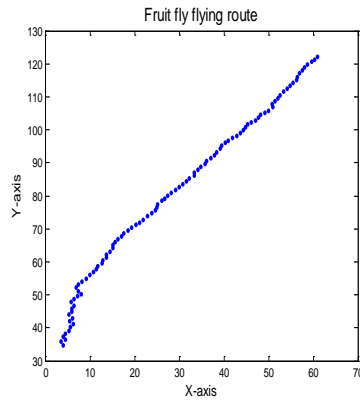
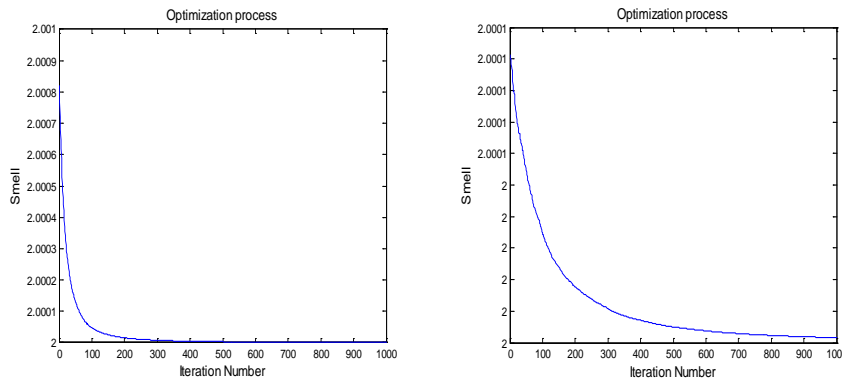

Fig. 1 fruit fly flying route



Fig. 2 (a) The best fitness based on IFOA    Fig. 2 (b) The best fitness based on FOA
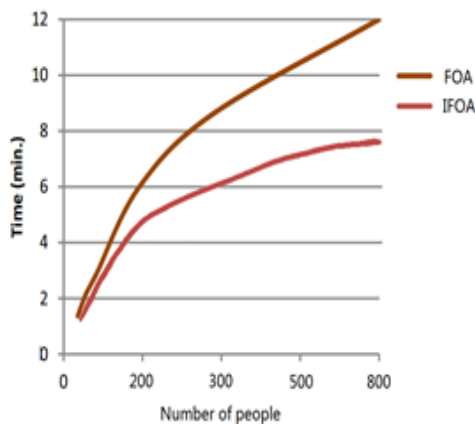


Fig. 3. The average evacuation time
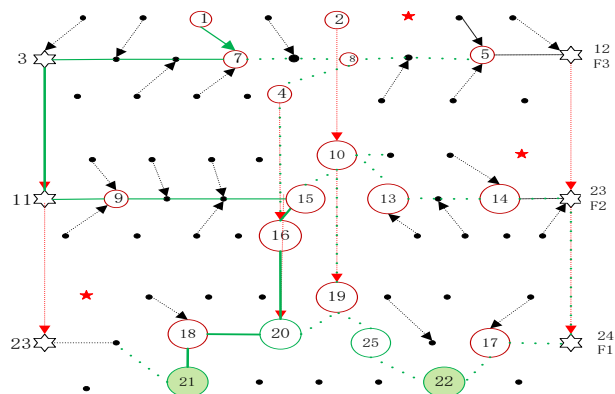for different number of people

Fig. 4. The optimum evacuation
routes in the building

## Conclusion and Future Work

This paper propose a new macroscopic swarm intelligence model where fire, smoke, and individual factors can guide a crowd to rationl escape. By dispersing passages capacity, to avoid

possible disorder and blocking. The algorithm has been proved feasible and effective after test the database.

In future work, we consider to study the use of adaptive evacuee routing techniques that can help better evacuate. Future work on swarm intelligence algorithms will also consider a realistic distribution of users in the building.

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