Parallel Ant Colony Optimization for Evacuation Planning

Manel Hajjem*
LARODEC, ISGT
University of Tunis, Tunisia
hajjem.manel@gmail.com

Hend Bouziri
LARODEC, ESSECT
University of Tunis, Tunisia
hend.bouziri@gmail.com

El-Ghazali Talbi
LIFL
University of Lille, France
El-ghazali.Talbi@univ-lille1.fr

Khaled Mellouli
LARODEC, IHEC Tunis
University of Carthage, Tunisia
khaled.mellouli@topnet.tn

ABSTRACT

The management of emergency situations is considered as a complex field due to its confusing situations as well as its difficulty in anticipating the behavior of evacuees while dealing with such disasters. Therefore, it is necessary to establish an efficient evacuation plan that should simulate real-life evacuation process. This paper defines the earliest arrival flow problem with load-dependent travel time (EAFP-LDT) as the more adequate macroscopic model for evacuation plan. We maintain the load-dependent travel time constraint since it defines the dependence between the crowd's rate and the travel time in doors. To solve this problem, we propose a parallel ant colony optimization algorithm (PACO) to deal with the emergency evacuation guidance problem in buildings based on EAFP-LDT. This proposed algorithm provides a realistic and an efficient evacuation plan which permits evacuees to follow the shortest path with less crowd.

KEYWORDS

Emergency evacuation, Crowd modeling, Earliest arrival flow, Parallel ant colony

1 INTRODUCTION

Due to the large number of disasters instances across the world like fires, earthquakes and terrorist attacks, the development and the assessment of emergency evacuation plans have gradually become primordial. However, an efficient evacuation plan is seen as a challenging system as the behavior of pedestrians- while dealing with emergency situations- may be influenced by many factors. For example, the familiarity with the environment, tendency of herding, compliance with the rules and so on are some obstacles that may restrict the quick movement of those pedestrians in such situations. The elaboration of evacuation plan consists of the simulation of evacuation's circonstances as well as the definition of an adequate escape algorithm. According to the level of precision, two approaches have been used to model the problem [5]: The microscopic models and the macroscopic models.

Dealing with macroscopic approach, this paper treats the evacuation process using dynamic network flow model. In real-life evacuation process, the flooding of a city, the arrival of a violent storm or the collapse of buildings may occur before the previous evacuation time. Hence, it is primordial to safe the maximum of evacuees as quickly as possible. Therefore, we consider the earliest arrival flow problem with the load-dependent travel time model (EAFP-LDT) [4] in which the travel time of edges depends on the amount of flow not only entering the edge at a given time unit but also standing on this edge at this time unit. Our main contribution is to provide an evacuation plan based on EAFP-LDT that can be used by the decision maker during preparedness and response phase. To put this objective into practice, we suggest a parallel colony optimization (PACO) in which the different ants in the colony evolve in parallel as evacuees do.

2 PROBLEM DEFINITION

We consider the dynamic network $G_T = (N, E, T)$ where the horizon time T defines the required time to finish the evacuation process. the building rooms are represented by the set nodes N, and the set E of edges corresponds to connections between these parts such as doors, stairways and elevators. Therefore, the earliest arrival flow model aims to maximize simultaneously the flow reaching the sink at each unit time of the horizon T. The EAFP-LDT which will be taken into account in this paper was studied by Baumann and Köhler [1]. In this work, authors have proposed an approximation which is proved theoretically.

3 PARALLEL ANT COLONY OPTIMIZATION FOR THE EAFP-LDT

In terms of macroscopic emergency evacuation models, several ACO has been applied [2, 3]. Most of these works are based on sequential implementations. However, sequential ant colony optimization lacks adequate results representing the evacuation process. Consequently, our main attribution is to provide a parallel implementation of the ACO schema that can be useful to allow people to escape during emergency situations.

The core idea of PACO is presented in the flowchart given in Figure 1.

*Corresponding author

GECCO '17 Companion, Berlin, Germany
 978-1-4503-4939-0/17/07…$15.00
DOI: http://dx.doi.org/10.1145/3067695.3076058

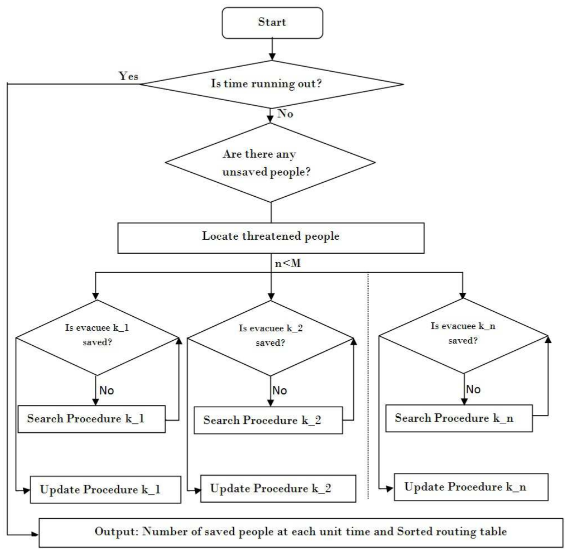

Figure 1: Flowchart of PACO.

4 EXPERIMENTAL RESULTS

In this section, we present the computational results of our PACO implementation to deal with the EAFP-LDT in building emergency evacuations. The PACO algorithm was implemented using C++ language. The experiments were conducted on the first floor of an office building from Tunisia represented by a network containing 30 nodes and 36 edges. Since it is primordial to save people as earlier as possible, we plot the distribution of saved evacuees over time in two cases; when the initial number of persons is equal to 400 and when it is equal to 600.

As we can see in figure 2, in the first case, once initial people are equal to 400, almost all people are safe in the early periods , which is mainly the target of our emergency evacuation plan with the EAFP formulation. However, in the second case (initial people are equal to 600), more people remain in the building in the last period. Therefore, to analyze deeply these situations, we make the following observations :

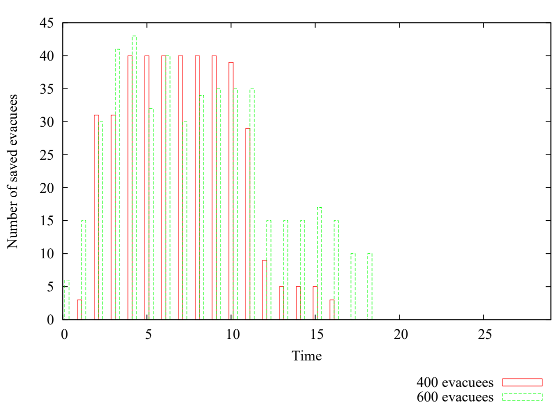

Figure 2: Distribution of saved evacuees over time.

- The number of secured people during the first two-unit time increases slowly. This corresponds to the initial generations of ants when people are not yet conscious of emergency situations and even they do not know yet the set of accessible paths.
- The maximum number of evacuees is saved before period 12. In fact, in our proposed model, ants are able to detect shortest and less crowded paths which is convenient in the evacuation process. This means that our model can provide best itineraries to evacuate people.
- In the last periods, remained people are consistently and slowly evacuated. This reflects the bottlenecks that we may find in any real-life evacuation process. At the beginning situation, 400 persons exist in the building. All of them are ultimately evacuated form the building. However, in the case of 600 persons, unsaved people remain in the building at the end of the horizon time.

5 CONCLUSION

In this paper, we have studied the emergency evacuation problem from a combinatorial optimization perspective. We have modeled the evacuation process as the earliest arrival flow problem with load dependent travel time. Then, we proposed a parallel ant colony algorithm called PACO. This method has given interesting information about the building safety. As future work, we aim to integrate specific information on each ant to deal with microscopic level.

REFERENCES

[1] N. Baumann and E. Köhler. 2007. Approximating earliest arrival flows with flow-dependent transit times. *Discrete applied mathematics* 155 (2007), 161–171.

[2] E. Forcael, V. González, F. Orozco, S. Vargas, A. Pantoja, and P. Moscoso. 2014. Ant colony optimization model for tsunamis evacuation routes. *Computer-Aided Civil and Infrastructure Engineering* 29, 10 (2014), 723–737.

[3] M. Goodwin, O.C. Granmo, and J. Radianti. 2015. Escape planning in realistic fire scenarios with Ant Colony Optimisation. *Applied Intelligence* 42, 1 (2015), 24–35.

[4] E. Köhler and M. Skutella. 2005. Flows over time with load-dependent transit times. *SIAM Journal on optimization* 15 (2005), 1185–1202.

[5] H. Vermuyten, J. Beliën, L. De Boeck, G. Reniers, and T. Wauters. 2016. A review of optimisation models for pedestrian evacuation and design problems. *Safety science* 87 (2016), 167–178.