VICTIM EVACUATION FROM A BUILDING UNDER DISASTER

Ankitha Pille
Michigan Technological University
Houghton, MI USA
apille@mtu.edu

ABSTRACT

In emergency scenarios, it is important to guide victims towards the exit or the first responders towards the victims in order to rescue them. Rescue operations are quite complex in indoor environments as the information within the building is unknown. Decision should be made on the number and way the rescue team should be dispatched within the building. The objective for a search and rescue problem is to provide optimal rescue path to the victim. Ant colony optimization algorithm(ACO) is a swarm intelligence algorithm that replicates the behaviour of ants, searching for food. Number of research studies showed that ACO can be used for evacuation planning. This paper is about using ACO in various emergency scenarios and discuss some of the limitations of using ACO and scope of my future work in this area.

INTRODUCTION

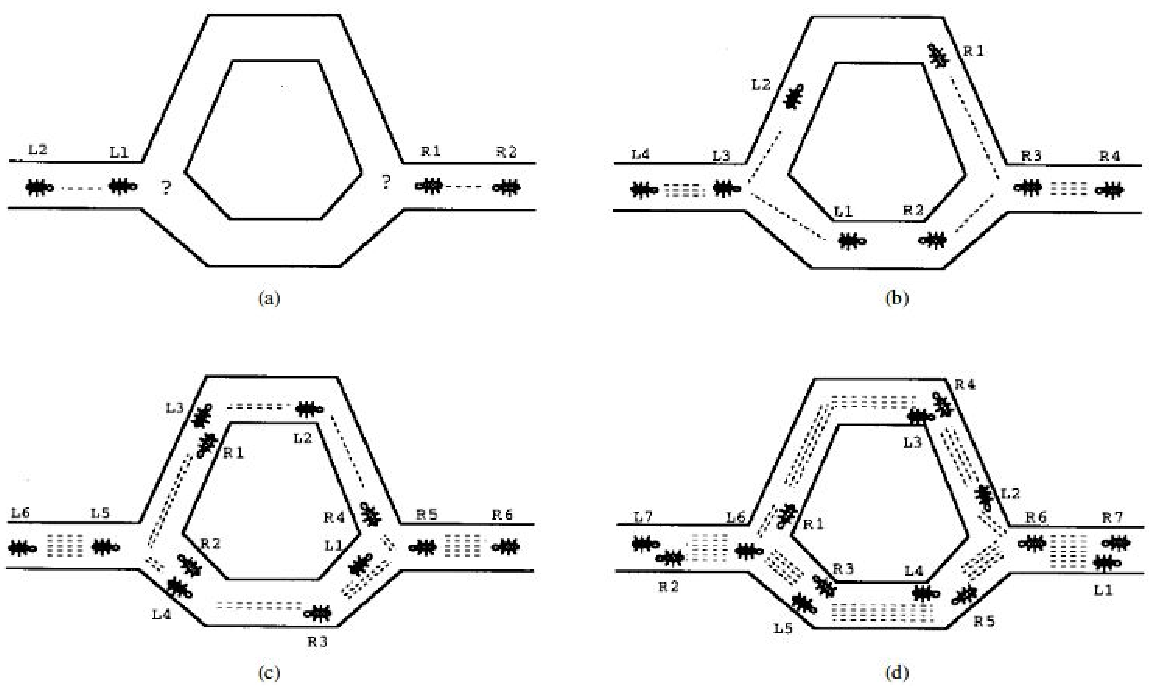
In most of the disaster scenarios, the environment within the building is unknown and changing dynamically because of the structural hazards within the building. The shortest path algorithms such as A*, Bellman ford, Dijkstra, Kruskal and Prim's requires the floor plan of the building to be known in advance which is not usually feasible as most the victims or first responders are unfamiliar with the building structure, also there algorithms are basically static in nature . We have to rerun the algorithm with new changes in cases when floor plan of the building changes due to the disaster, however ACO is dynamic, it can continue execution by adding new changes.

Determining the best route with low risk is most important in evacuation planning. Victims and the responders do not have full information of the situation within the building, the objective for the victims is to find the shortest route towards exit and the objective for the first responder is the search for the victim in every possible point within the building and then find the shortest route towards exit to evacuate the victims and themselves as soon as possible.

BACKGROUND AND LITERATURE REVIEW

Ant Colony algorithm is one of the swarm intelligence algorithm and has been widely used to finding shortest path in various application. It has also been attracted attention in the search and rescue operations. This algorithm is inspired by the behaviour of ants, searching for food. It was originally proposed by Dorigo et al[1] and has been widely used in finding shortest path on graphs.

Ants communicates indirectly through stigmergy by using a chemical substance called pheromone left by other ants on the path. Each ant makes decision on which route to follow based on the amount of pheromone on that route. Since more pheromone gets accumulated on the shorter path than on the longer path in less time. Ants tend to follow the shortest path as shown in the below figure.



a) Ants has to decide which route to follow
b) Ants randomly selects one route. Some chose upper path and some lower path. Each of the ants spread pheromone on the route it travels
c) Since every ant travels at a constant speed, ants taking shortest path, reaches the opposite direction early as compared to the ants travelling on the longer path
d) Pheromone accumulates at the higher rate on the shortest path and hence more ants gets attracted towards the shortest path and eventually most of the ants takes shortest path.

ACO algorithm is inspired by the above foraging behaviour of the ants. ACO is mainly used in finding shortest path in the graph, where one of the node represents nest /source of the ant, one node represents the food/destination, while rest are the intermediate nodes through which the artificial ant can traverse. A pheromone value τ_{ij} is associated with each edge (i,j) and the decision of ants on which edge to select next depends the value of τ_{ij}. Higher the value of τ_{ij}, higher will be the probability of selecting the edge. Pheromone values for every edge gets updated on each iteration by 1) Pheromone deposit and 2) Pheromone evaporation. In addition to the pheromone value, a heuristic value also plays a role in determining which edge to select next which is given by the inverse of the distance between nodes i and j, $\eta_{ij} = 1/d_{ij}$

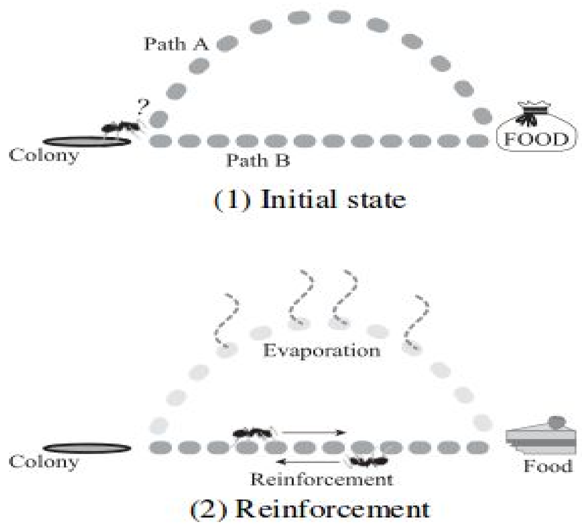
Thus the probability of selecting edge (i,j) can be given as

$$\rho_{i,j} = \frac{[\tau_{ij}^{\alpha}][\eta_{ij}^{\beta}]}{\sum_{h \varepsilon N^k} [\tau_{ih}^{\alpha}][\eta_{ij}^{\beta}]}$$

Where N^k is its possible neighborhood. $\rho_{i,j}$ is the probability of selection between nodes i and j for any ant, τ_{ij} is the quantity of pheromones on the edge (i, j), η_{ij} is the heuristic factor for the selection of the edge, it is defined as the inverse of the distance($1/d_{ij}$)between nodes i and j, α is the controlling factor of the influence of τ_{ij} and β is the controlling factor of the influence of η_{ij}.

The ACO algorithm mainly consists of two steps:

1) Exploration Phase: In this phase each ant search randomly for the destination and the goal is to provide an initial path for each ant from the source to the destination
2) Operation Phase: Once the ants finds destination, they communicate it to the rest of the ants by spreading pheromone, Other ants decides on selecting the edge based on the probability given above, which depends on the pheromone level and the heuristic value of the edge. After each ant completes its tour, pheromone on each edge of its tour is updated. Updation takes place in two levels.
    - Firstly, pheromone evaporation is applied to decrease the pheromone values on every edge by a constant rate. The objective behind pheromone evaporation is to restrict unnecessary increase of pheromone level and to forget the poor choices done in the earlier stages
    - After the pheromone evaporation is applied. Pheromone deposit takes place on the edges belongs to the tour, ants completed successfully.



Number of research studies has been conducted in improving Ant Colony optimization algorithm for providing optimal shortest path in the graph.

In 1992, M. Dorigo proposed ant colony algorithm. Due to the randomized nature and dependence only on pheromone level, it tends to either slow convergence rate or stagnation. The algorithm takes longer time to find the optimal route or provides a suboptimal route because more pheromone on that route, ignoring the optimal route as no ant chose the optimal route. Later on scholars developed some improved ant colony algorithms to handle slow convergence rate and avoid stagnation. In 1997 Dorigo et al. proposed ACS (ant colony system)[2]. Sttzle&Hoos proposed MMAS (max-min ant system) in 1999 [3]. Maniezzo proposed ANTS (approximate nondeterministic tree-search) procedures in 1999 [4]. Cord n et al. presented BWAS (best-worst ant system) in 2002 [5]. Blum et al. presented hyper-cube framework ant colony algorithm 2004 [6]. Xinlu Zong et al. developed multi-objective ant colony optimization model to solve massive evacuation problems in complex traffic conditions, and multi-ant colony system was presented to tackle mixed traffic evacuation problem [7-8]. Ant colony algorithm had gained many outstanding achievements in combinatorial optimization, computer network routing, continuous function optimization, robot path planning, data mining, grid optimization and other fields. G.Shang [9] proposed a hybrid approach which combined ant colony algorithm with genetic algorithm. S.G.Lee [10] introduced a pheromone control technique using a curve-fitting algorithm.

PROPOSED SYSTEM

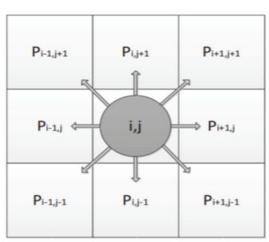
ACO has also been widely used in route optimization problems in disaster scenarios, however such scenarios are multi objective model. We have victims in multiple locations and continuously moving, there are multiple exits from which the victim can be evacuated. Hazards within the building are dynamic, hence the floor map will be changing continuously and ants may require to operate in new environment different than the previous iteration

When emergency occurs within a building, the first thing the responder must know is the location of the victim. Using the location of the mobile phone, the evacuation system can get to know the location of the victim. Using the present location of the victim as the source and the exit as destination, the evacuation system can run ACO algorithm to give a optimized route to the victim.

The objective of this optimization is not only reducing the time required to evacuate, but also avoid congestion situations within the building. For example if we have two exits at the same distance. The traffic of victims should be equally divided among these two exits to avoid congestion.

The Evacuation plan can described in the below steps.

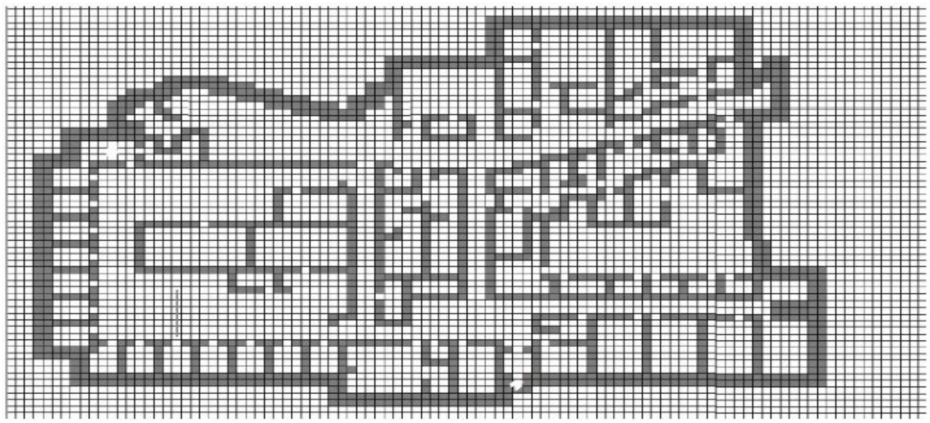
1) Structure of the building are complex, to run simulation we need to transform the floor map of the building into simpler form. This paper uses a cellular automata model, which is a two dimensional grid of cells and from each cell there is a possibility to move only to eight neighboring cells.
   One of major assumption in this model is that no two victims occupies the same cell and if multiple victims are competing to occupy one cell, then one of them is selected randomly

   After dividing the floor map into two dimensional grid, it is required to identify the exits and already existing walls for the initial run of the algorithm.

The walls and the obstacles are made inaccessible by assigning the pheromone level on those grids equal to infinity.

Below figure shows how a floor map can be divided into grid



2) Once the floor map is ready, the second task is to localize the victim on the floor based on the their location. Location of the victim can be determined by the location of their mobile phone.

3) The next step would be to run the ACO algorithm for each victim. For each victim we run multiple ants towards each exits. Ants will spread pheromones and eventually the algorithm will provide the shortest path to the nearest exit as more pheromone gets accumulated on the shorter route.

ACO algorithms have few disadvantages when used in building disaster scenarios.

- Evacuation time is very crucial in disasters, because of the randomized nature of ACO, it takes more time than any other shortest path algorithm.
- Ants running for one victim must be distinguished from the ants running for other victims
- The route suggested is not always optimal, ants may select a suboptimal route randomly, suboptimal route may become more attractive for the ants because of high concentration of pheromone on it, ignoring the optimal route.

Because of all the above limitations ACO cannot be directly used in disaster scenarios

Some of the research studies suggested to use ACO in exploring the area i.e to locate victims and hazards and then using other shortest path algorithms to determine the shortest distance route from any location towards the nearest exit. This exploration is done using robots. Robots

explores the area and leave tags on the floor, other robots can read those tags to determine if they have already been explored by other robot or yet to be explored. As discussed above, evacuation time plays an important role, hence we cannot wait until area exploration is complete before starting evacuation of victims, Thus the exploration and evacuation must be overlapped.
Research has been done by Sven Koenig and team[11] in finding target in games where he overlapped the process of searching the path towards the target and planning the move at the same time. They introduced Time Bounded Adaptive Algorithms, which instead of exploring the whole area at once, interrupts the search after a fixed number of state expansion and select most desired cell for the next move. For example in case of A*, cell with least f(n) value will be selected. If the selected cell is in the same path the agent is currently situated in, follow the path to the target cell and if it is in different path, backtrack and move towards the new path. If agent detects an unknown obstacle, make the heuristic of the grid as infinity.

They also introduced Incremental Heuristic Evaluation. If the agents detects previously unknown obstacle it has to replan, however complete recomputation of the best plan is unnecessary, some of previous search results can be used.

Although their research was primarily on game environment, however some of these concepts can also be used for the future work of this paper.

CONCLUSION

Evacuation became an important problem with considering different objectives simultaneously. It is important to find an optimization strategy to reduce the damage to people's lives and properties during the evacuation process.

In most of scenarios, Victims and First responders trying to rescue the victims are not aware of the structural changes within the building after disaster. Ant Colony Optimization algorithm because of its dynamic nature can be useful in such scenarios where the prior knowledge of environment is not available. ACO algorithm has few major disadvantages which restricts it to be used directly in disastrous building. Few studies suggests using ACO algorithm in exploring the area. Before making any decision on the rescue operation, the exploration of area must be done, however we cannot wait to rescue victims until the exploration of entire building is complete. It requires to overlap the exploration and execution phases of the evacuation. Few other studies introduced this overlapping in game environment, future work of this paper included applying those concepts in the building rescue operation.

FUTURE WORK

To the best of my knowledge, not much work has been done in the area of merging exploration and evacuation in emergency scenarios. Future work of this paper includes finding scopes for overlapping these two in disaster management and studying its impact on evacuation time.

Several other features also have impact on the evacuation, it includes the velocity/speed of the victim. The person of age between 20-35 may have a different walking speed than a person of age above 35. The mobility of the person also plays a role. If the person is injured, then they might have to carried by some other person, which increases the evacuation time for the injured person as well as the person carrying them. The visibility inside the building can also have an impact, it may also increase the evacuation time. Future work of this paper also includes determining the impact of some of these factor in the Evacuation process.

One of the major challenge faced in evacuation is the Traffic/Congestion. If we have multiple exits in the building. It is possible that the algorithm suggests same exit to all the victims causing congestion/traffic on one exit, further reducing the evacuation rate, instead victims can be effectively distributed over multiple exits.

REFERENCES

[1] M.Dorigo, V.Maniezzo, A.Colorni, “Ant system: optimization by a colony of cooperating agents”, IEEE Trans. on Systems, Man and Cybernetics , Part B, Vol.26, No.1,1996, pp.29-41

[2] M. Dorigo and L. M. Gambardella, "Ant colony system: a cooperative learning Approach to the traveling sales man problem," IEEE Transaction on Evolutionary Computation, vol. 1, pp.53-56, 1997.

[3] Sttzle and Hoos. “MAX-MIN ant system and local search for combinatorial optimization problems-towards adaptive tools for combinatorial global optimization”, 1999.

[4] Maniezzo V. Exact and approximate nondeterministic tree-search procedures for the quadratic assignment problem [J], INFORMS Journal on Computing, 1999, 11(4):358-369.

[5] Cord n O, Deviana I F, Herrera F. Analysis of the best-worst ant system and its variants on the TSP [J], Mathware and Soft Computing, 2002, 9(2-3):177-192.

[6] Blum C, Dorigo M. The hyper-cube framework for ant colony optimization [C], IEEE Transactions on Systems, Man and Cybernetics, 2004.

[7] Xinlu Zong, Shengwu Xiong, Zhixiang Fang, Wanru Lin. Multi-objective Ant Colony Optimization Model for Emergency Evacuation, Natural Computation (ICNC), 2010 Sixth International Conference on.

[8] Zhixiang Fang, Xinlu Zong, Qingquan Li, QiuPing Li, Shengwu Xiong. Hierarchical multi-objective evacuation routing in stadium using ant colony optimization approach, Journal of Transport Geography, 2011.19(3):443-451.

[9] G.Shang, J.Xinzi, T.Kezong, “Hybrid Algorithm Combining Ant Colony Optimization Algorith m with Genetic Algorithm”, Proc. ofChinese Control Conference , 2007, pp.701-704.

[10] S.G.Lee, T.U.Jung, T.C.Chung,Improved ant agents system by the dynamic parameter decision, Proc. of 10th IEEE International Conference on Fuzzy Systems , Vol.2, 2001, pp.666-669.

[11] http://idm-lab.org/projects.html