Rapid Evacuation System by K-means clustering and Particle swarm Optimization

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Abstract : **The objective of this paper is to develop a agent leader based rapid evacuation plan by using Particle swarm Optimization and K means clustering algorithm. Conventional evacuation plans consisting of exit signs and markings have lost their usability in modern day's building which are complex and convolute. The K mean clustering algorithm solves the congestion problem and Particle swarm Optimization ensures panic and jostle free evacuation.**

IndexTerms **- Evacuation plan, Human behavior simulation, K-means clustering, Particle swarm Optimization.**

I. Introduction

The primeval man used to plan his habitat with probability of hazards in mind. Nevertheless with the advancement in science and technology complexity of human habitat increased manifold and so did the population density. Subsequently risks of human life in case of hazard increased especially in densely populated facilities or buildings like hospitals, schools, shopping malls, offices etc. Due to higher number of casualties involved it is mandatory for the employer or owner to provide proper exits, equipment, information and training to prevent death and injuries in case of an emergency. However, safe evacuation of occupants in an emergency can be a herculeantask due to widespread panic and jostling in crowd.In such a condition an orderly and systematic evacuation planned in advance can prove to be beneficial. The evacuation plan can be effective and successful if the exit routes are clearly marked and are located at convenient places. Furthermore, trained professionals should be present at the exits to help people find their way out of the building quickly and systematically to prevent jostle. The trained professionals may be employees of the organization, who have received special training or they may be outside help forces. Evacuation time is enormously influenced by walking speed of different people as depicted in table 1[1][2]. The leaders should consider that the walking speed of certain special groups like children, elderly and disabled persons may not be comparable to the speed of crowd, so they should move forward with an optimum speed

According to a report submitted by National Crime Records Bureau of India[4] , in year 2014 a total of 20,201 deaths in the country were attributed to forces of nature whereas 6,36,509 cases of 'un-natural accidents' were reported in which 3,16,828 persons died and 4,94,096 persons injured. The 'un-natural accidents' is defined as accidents caused due to human negligence, for instance traffic accidents, fire accidents, electrocution etc. Fire accidents occupy a considerable share in un-natural accidents. The report also declares that a total of 20,377 cases of fire accidents were reported in the country rendering 19,513 deaths and 1,889 injuries. Moreover, 50.0% or more cases of fire accidents were reported in residential buildings or dwelling. Furthermore the number of casualties increases due to improper or inefficient evacuation plan. Thus simulation of an evacuation plan using sophisticated mathematical models is important for risk assessment.

To minimize the number of casualties the government declared planning a proper evacuation plan mandatory as well as laid standards for developing an organized evacuation plan. However even if proper standards are followed while designing an exit route and exits are clearly marked the widespread confusion and jostling created in crowd due to panic leads to huge loss of life and property . In an emergency evacuation certain special groups like children, elderly and disabled persons are affected the most .The following points summarizes the obstacles and complications involved in safe evacuation of people

- Confusion: It is natural tendency of a human being to get perplexed if he is required to make split seconds decisions in a scenario endangering his life.
- Congestion: The jostling and panic in crowd attributes to congestion of a particular exit route.
- Inability to follow up: As mentioned earlier certain special groups like children, elderly and disabled persons are affected the most due to their slow walking speed and inability to follow and catch up with the crowd.

The proffered research report presents an algorithm for safe evacuation of people from a facility in case of an emergency.The ultimate goal of the research is to develop an evacuation plan for safe and quick evacuation of people and ensuring that no one is left behind. The K-mean clustering algorithm is employed to cope up with the above mentioned problems ofconfusion and congestion by dividing people into appropriate clusters or groups.The bubble sort algorithm is applied to determine the optimum walking speed so that even special groups can follow the group.The swarm algorithm is used to enable people systematic and organized evacuation of people hence avoiding panic and jostling.

II. METHODOLOGY

Our project proffers a rapid evacuation system by amalgamation of k mean clustering, bubble sort and particle swarm optimization techniques. The developed human behaviour simulation is shown in Fig.2.1 Two types of individuals are considered, namely agents and leaders. The agents (a1, a2, a3…a11) are the occupants of the facility. Leaders (L1 and L2) represent the individuals with superior training and knowledge and perform task of guiding the agents towards exit discharge. The area in red shade is the evacuation area, exit route is marked by yellow colour and exit discharge or safe location is shown by green colour. The black lines characterises two exit accesses (E1 and E2).

The simulation starts with random assignment of the individual speed. The individual move towards exit access E1 or E2 depending upon the relative distance . Thus two clusters are formed by K-mean clustering algorithm. The clusters after reach the exit access where the assigned leader is already present. The leader waits till all agents have reached the exit access and then moves with the speed of the slowest member to ensure that no one is left behind. Bubble sorting algorithm assists leader in this task. Agents follow the leader towards exit discharge by particle swarm optimization.The flowchart of the proposed evacuation system is shown in Fig 2.2.

2.1 Algorithm

Step1: Initialise coordinates(x, y) of agents (a1, a2….a11) and leaders (L1 and L2).

Step2: Allocate random speeds (v1, v2….v11) to agents (a1, a2….a11).

Step3: Evaluate distance of each agent from exit access E1 and E2(d_{E1} and d_{E2}) .

Step4: Check if distance of an agent from exit access E1 is greater than E2($d_{E1} > d_{E2}$) .

Step5: If true accelerate the agent E2and vice versa.

Step 6: Check if all agents have reached exit access.

Step 7: If true Obtain speed of slowest member in group. (v_{min}) by bubble sort else wait for all members to reach exit access.

Step 8: Assign leader speed as (v_{min}).

Step 9: Form group or swarm by Particle swarm Optimization and move towards exit discharge.

Step 10: Check if Exit Discharge reached.

Step 11 : if true stop else continue moving.

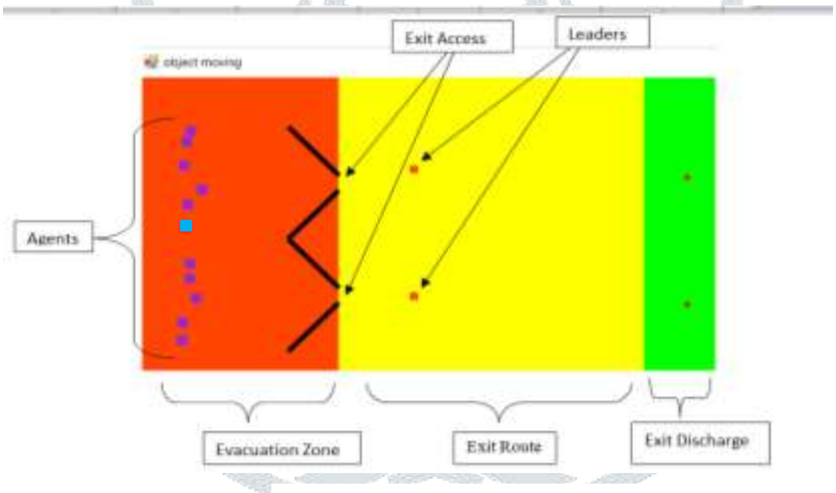

Fig 2.1 Simulation Layout

2.2 Equations

The developed mathematical equations are as shown below. The equation 1 and 2 calculates the Euclidian distance of agenta_i from exit E_1 and E_2 respectively. The coordinates of exit access E_1 and E_2 is represented by (x_{E_1}, y_{E_1}) and (x_{E_2}, y_{E_2}) respectively and (x_{a_i}, y_{a_i}) represents coordinates of ith agent. Equation 3 determines the group number or cluster number of agent by K-means clustering. The agent nearer to exit access 1 is assigned cluster E_1 and the agent nearer to exit access 2 is assigned clusterE_2. If a agent is at equal distance (blue coloured agent) from both the exit access then the cluster number is decided by minimum walking speed of both groups. Equation 4-5 represents the Particle swarm Optimization. Equation 4 and 5 demonstrates the updation of x and y coordinates of agent. Random function denoted by rnd() is used to make motion of agents random and hence simulate human behavior..$\boldsymbol{V_{a_i}}$represents the updated velocity of the agent. The instantaneous velocity of agent depends upon velocity of leaders(V_{l_j}) and the global best velocity(V_{gbest}).(x_{l_i} and y_{l_i}) represents the coordinated of the leader .Equation 7 and 8 demonstrates how these are updated. Due to the constraints applied in equation 7,8 and 9 the leaders start moving only when all particles have reached exit access and they move with the velocity of the slowest agent which is represented here as global best velocity(V_{gbest}).

$$d_{a_i,E_1} = \mathrm{sqrt}((x_{E_1}{}^2 - x_{a_i}{}^2) + (y_{E_1}{}^2 - y_{a_i}{}^2)) \qquad (1)$$

$$d_{a_i,E_2} = \mathrm{sqrt}((x_{E_2}{}^2 - x_{a_i}{}^2) + (y_{E_2}{}^2 - y_{a_i}{}^2)) \qquad (2)$$

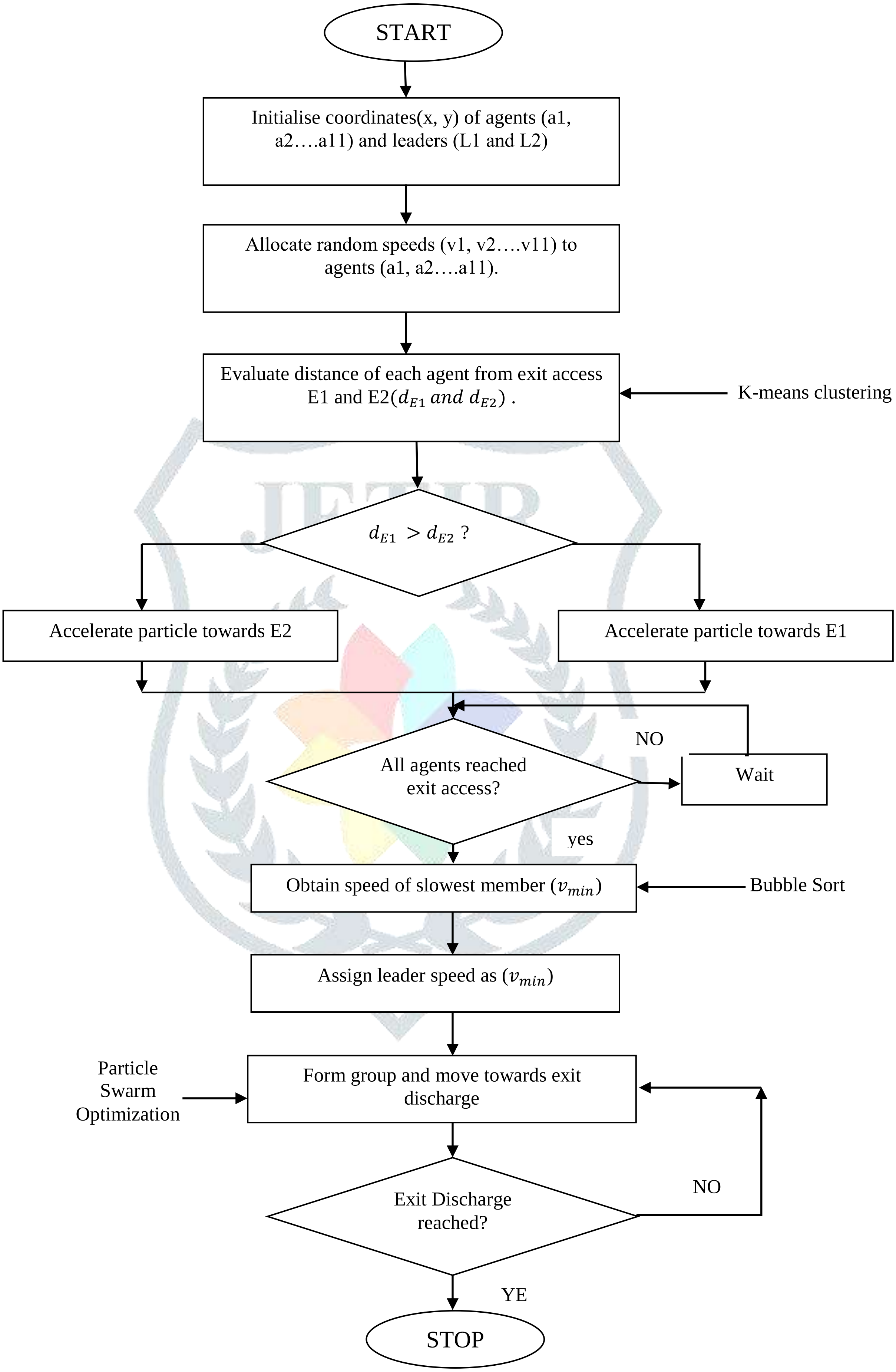

Fig 2.2Flowchart of proposed evacuationplan

$$\text{clstrNo}=\begin{cases} E_1, d_{a_i,E_1} < d_{a_i,E_2} \\ E_2, d_{a_i,E_1} > d_{a_i,E_2} \\ \begin{Bmatrix} E_1, V_{minE_1} < V_{minE_2} \\ E_2, V_{minE_1} > V_{minE_2} \end{Bmatrix}, d_{a_i,E_1} = d_{a_i,E_2} \end{cases} \quad (3)$$

$$x_{a_i} = \{x_{a_i} + 1, x_{a_i} < 200\} \quad (4)$$

$$y_{a_i} = \begin{Bmatrix} y_{a_i} + rnd(), clstrNo = E_1 \\ y_{a_i} - rnd(), clstrNo = E_2 \end{Bmatrix} \ldots\ldots\ldots \quad (5)$$

$$\boldsymbol{V_{a_i}} = \begin{Bmatrix} V_{lbest}, x_{a_i} < 200 \\ 0, V_{l_j} = 0 \\ V_{gbest}, V_{l_j} > 0 \end{Bmatrix} \quad (6)$$

$$x_{l_i} = \begin{Bmatrix} x_{l_i} \quad , x_{a_i} < 200 \\ x_{l_i} + 1, 200 < x_{a_i} < 500 \end{Bmatrix} (7)$$

$$y_{l_i} = \{y_{l_i} + rnd(), x_{l_i} < 500\} (8)$$

$$V_{l_j} = \begin{Bmatrix} 0, x_{a_i} < 200 \\ V_{gbest}, x_{a_i} \geq 200 \\ 0, x_{l_i} \geq 500 \end{Bmatrix} (9)$$

III. RESULTS AND DISCUSSION

The application as developed in Microsoft Visual Studio is shown in the figure.3.1 the area in red shade is the evacuation area, exit route is marked by yellow colour and exit discharge or safe location is shown by green colour. The black lines characterises two exit accesses (E1 and E2).Before starting the simulation speeds of agents are initialised by a random function to represent a real life situation (figure.3.3).The randomize button is clicked for this purpose.

The simulation starts after start button is clicked(figure.3.2) and all agents move towards the appropriate exit access as determined by k mean cluster analysis. The leader waits for the agents at exit access ((figure.3.3-3.6)). The speeds of the agents can be seen in the column under random function result and the instantaneous position can be seen in the column named X-Coordinate. The leader moves forward only when all agents have reached the exit access.Once all agents have reached the exit access the leader moves towards exit discharge with the speed of slowest member in group (figure.3.7).The formation of swarm by PSO is evident.The simulation stops when all the agents have reached a safe location or exit discharge(figure.3.8).

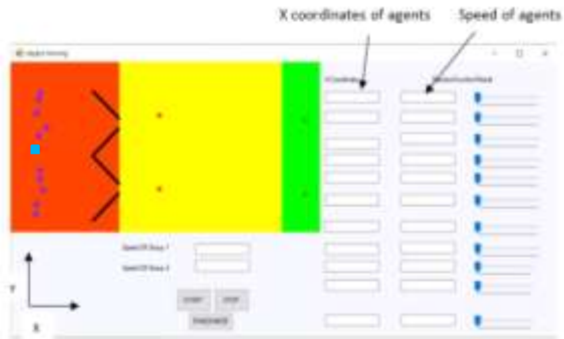

Fig 3.1Position And Speed Of Agents

Fig 3.2Randomize function

Fig 3.3Starting of simulation

Fig 3.4Simulation in progress

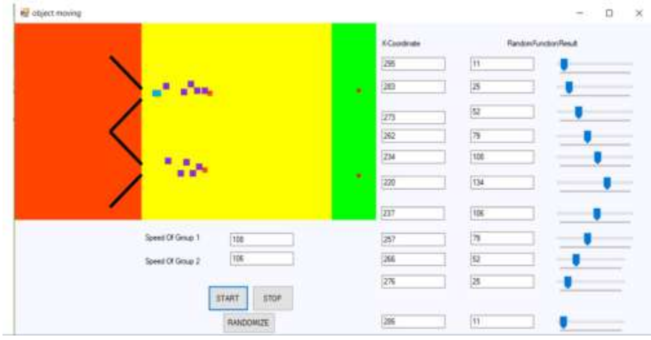

Fig 3.5Agents approaching leader

Fig 3.6Leader waits at exit access till all agents reach it

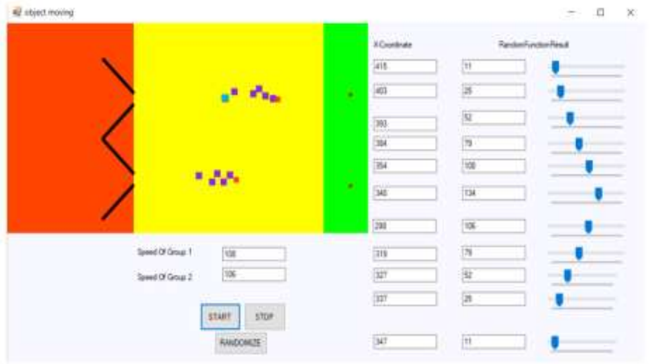

Fig 3.7Leaders accompany the group towards exit discharge

Fig 3.8Simulation stops when all agents and leaders reach exit discharge

IV.Conclusion

In the project a rapid evacuation plan by simulation of human behaviour is successfully implemented. The novel evacuation plan is developed by amalgamation of K-means clustering, bubble sort and Particle swarm Optimization. Agents walk with random and different speeds. This represents a practical scenario as walking speed vary with age, gender and physical health. In human behaviour simulationtwo different individuals are considered, Agents and Leaders.

V.Future Scope

The developed rapid evacuation plan can also be implemented in other areas such as traffic management, Internet bandwidth management, Internet traffic management etc. Future research is needed in these areas. The hardware and software configuration decides the limitations of human behaviour simulation .More specific research is needed for application of the developed rapid evacuation plan and human behaviour simulation in complex facilities consisting of multiple floors.

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