Emotional Ant Based Modeling of Crowd Dynamics

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Abstract

It is known that one of the most disastrous forms of collective human behavior is the kind of crowd stampede induced by panic. This situation often leads to fatalities as people are crushed or trampled. This problem has been well researched from a socio-psychological point of view. In this paper we attempt to study and analyze the crowd behavior by using an Ant Colony Optimization (ACO) based computational framework. The initial simulations refer to a panic situation generated in a few connected cities of a war affected country.

1 Introduction

When people are part of a crowd, they often behave differently than if they were by themselves. Crowds often act overly frantic or fearful. The shout of 'FIRE!' in a packed movie theater will result in a stampede to the door. Sometimes, crowds behave in a cruel and violent manner. The lynch mobs in America at the turn of the century are a classic example of how barbaric people can be when they are in a crowd. Crowds can also be apathetic. Often people will act as bystanders to an assault on another person without doing anything to help the person being assaulted.

What is the cause of crowd behavior? This question has intrigued psychologists for decades. The answer appears to depend on the type of crowd behavior and sometimes on the context in which the behavior is shown. Some psychologists suggest that group hostility can arise as a result of de-individualization. De-individualization refers to a weakened sense of personal responsibility. In other words, since people feel anonymous in a crowd, they often act irresponsibly and without care for others. From a modeling perspective study of crowd events is appealing to social simulation researches, because their associated phenomena are largely emergent in nature. The recent lavish development of applied cognitive science [11] helps the researcher to evaluate the other hybrid models related to crowd behavior. The purpose of the present research is to create an efficient biologically inspired agent (ant colony model) to analyze emotion model of crowd. We expect the proposed model would have a phenomenal impact on many policies and strategies, as the model considers the crowd model and behavior for a war-infected region. Section 2 briefly presents few notions related to crowd pshycology. In Section 3 few existing models of crowd behavior simulation in different aspects of social boundary and their scientific significance which inspired the present work are investigated. Section 4 describes the role of bio-inspired agent for the proposed model and, subsequently how the newly introduced 'emotional ants' are constructed to model the crowd behavior during a war situation. Some simulation and illustrations are also provided. Results are analyzed in Section 5 followed by few conclusions in the last Section of the paper.

2 Pshycology of crowd

Crowd behavior represents a situation in which a large number of people in a given area behave simultaneously in similar way and have a similar goal, which might be different from what they would do individually.

The crowd is seen as a large group of individuals in the same physical environment, sharing a common goal (e.g. people going to a rock show or a football match). The individuals in a crowd may act in a different way than when they are alone or in a small group [20].

As Van Berger suggested in [1], we cannot easily reduce human behavior to a mathematical equation that can be plotted on a graph as a trend line or as a series of variables that we can examine in detail throughout history.

According to Le Bon's contagion theory [2], crowds exert a hypnotic influence over their members. Shielded by the anonymity of a crowd, people abandon personal responsibility and surrender to the contagious emotions of the crowd. A crowd thus assumes a life of its own, stirring up emotions and driving people toward irrational, perhaps violent, action.

As per Ralph and Killian's emergent-norm theory of crowd dynamics [19], social behavior is never entirely predictable, but neither are crowds as irrational. If similar interests may draw people together, distinctive patterns of behavior may emerge in the crowd itself. Crowds begin as collectivities, acting, and protest crowds - norms may be vague and changing as when, say, one person at a rock concert holds up a lit cigarette lighter to signal praise for the performers, and other follow suit. In short, people in crowds make their own rules as they go along.

Apart from the disastrous forms induced by crowd behavior, Surowiecki [21] has explored the wisdom of crowds. He argues that aggregation of information in groups, resulting in decisions that, are often better than could have been made by any single member of the group.

3 Related Research

There are several significant breakthroughs in the applied cognitive sciences concentrating mainly on the behavioral modeling of crowd using different paradigms. The behavior of pedestrians in different situations has been exhaustively detailed in the literature [12], [13], [14].

Yin et al. [23] worked on the characterization of crowd behavior in confined areas such as railway-stations and shopping malls using image processing for the measure of the crowd motion.

Calvert [10] developed the blackboard architecture that allows the animator to work cooperatively with a family of knowledge based tools.

Bouvier [5] presented a crowd simulation in immersive space management and a new approach of particle systems as a generic model for simulations of dynamic systems.

Helbing et al. [14] model the collective phenomenon of escape panic in the framework of self-driven manyparticle systems. The computer simulations of the crowd dynamics of pedestrians are based on a generalized force model, which is particularly suited to describing the fatal build up of pressure observed during panics.

Agent based models also have been proposed which begin to address the individual movement. Again a frequently cited model was by Helbing et al. [14]. The model is strongly physics oriented which calculates forces acting on agents to determine movement with excessive forces leading to agent injuries. Similarly there are other works, which describes the crowd modeling simulation in emergency situations.

In [17], Musse and Thalmann simulate the behavior of a collection of groups of autonomous virtual humans in a crowd. The model presents a method for describing the crowd behavior through the group inter-relationships .

Bruzzone and Signorile [8] are combining particle dynamics particle queuing for crowd analysis and control in a museum. The approach can be applied to model a real case study. The model can also easily be applied to other real world scenarios such as rail stations, stadiums, opera houses, passenger ships, etc..

Crowd control can be applied to many different areas, such as police operations [22], shopping center design, public park re-organization [9], rail station re-engineering [6] and epidemic diffusion.

Pedestrian traffic in large cities is modeled in [11]. The work presents a way of simulating an intelligent crowd behavior in a virtual city. There are also some work related to urban planning with the help of crowd movement.

In tune of present research there is substantial motivation to study the psychological part of crowd model. Considering all the major works it has been observed that there is significant gap between the crowd model and their emotion especially in an uncertain situation. The work we propose in this paper refers to a country or region in the war-affected situation and exhibits plenty of cognitive, behavioral and psychological impacts under different conditions.

Crowd event may accumulate and occur in several situations. Some of them can be:

- Panic situation after air raid
- Negotiation between town leaders and soldiers
- Searching for explosives and weapons
- Protest over the arrest essential commodity, if any.
- Domestic terrorist attack or gorilla war resulting looting, shouting slogans heckling etc.
- Even crowd gather after he groups of troops arrived in between.

Therefore, in the situation considered here, the country C comprising different towns, like t_1, t_2,........,t_n are affected with those crowd movements.

4 Proposed Model Using Emotional Ants

The main objective of the proposed model is to fabricate an emotion based analytical model of crowd behavior which in turn seems to be more realistic in uncertain environment. The agent used in this model is biologically inspired whose transition behavior is modeled using fuzzy logic [3].

In any corner of a region, during war the people moves from one city to another, the city dwellers as crowd also alter their positions. The problem could be more complicated if the third city is also war affected. So, four different cognitive behavior of crowd can be modeled using the same model:

- Anger (A)
- Selfish minded (S1)
- Confused (C)
- Sad (S2)

When a selfish minded crowd (only bother about their own shelter) meets an angry crowd from other city, both become confused, because each of their emotion is opposite. We have then:

A + S2 => 2C
S1 + C => 2S1 dominant model
A + C => 2A

Therefore likely behavior of crowd under different situations are as follows:

- The meeting of a selfish minded crowd and a sad minded crowd could result in a confused crowd
- Sad crowd could get angry if they are upset that some crowd components can be selfish when they are sad

In this case we have:

S1 + S2 => C+A
S1 + A => 2C
S2 + C => A +C

Let i and j be subjects of emotions, emotion carriers, person and modules. The subjects take their states s_i and s_j from the set e = {selfish, anger confused, sad} in the discrete time: for $t \in N$, s_i^t, $s_j^t \in E$. The subjects move in a physical space and collide with each other.

When confronted they update their emotional states:

$$S_i^{t+\delta} = f(S_i^t + S_j^t)$$

A relation between the molecules of x and y is seen as:

$$\{(f(x,y),\, f(y,x)\} \rightarrow \{z_1,\, z_2\},$$

where x, y, z_1, $z_2 \in E$.

On this basis, the war crowd is modeled using an emotional ant agent. We interpret the model of emotion through the extended model of ACO ([4]) with some flavor of parallel ant agent in a multi agent scenario. The model is well backed up using fuzzy if-then rule templates to monitor the emotional ant movement. This makes the hybrid model more smart to tackle any kind of input conditions.

The pheromone level belonging to one colony has different meaning for other colonies representing different crowd behavior. Therefore the pheromone communication is based on fuzzy if-then rules, by which emotions of ant agents are exchanged.

4.1 Pheromone Model of Emotional ants

As the model uses the foraging behavior of ants, the foraging tasks may be abstractly viewed as a sequence of two alternating tasks for each ant: start from a nest where panic situation occurs and moves to a safe place (food). In this problem, we simulate the situation through ant, so the affected city is the start place and the safe place is the goal state or vice versa. The ant agent receives a reward at goal state; at other state does not.

Ants exhibit satisfaction or reward $P(s)$ for transitioning to the desired goal (safe place) irrespective the emotional state of the crowd (selfish or sad and even confused). The utility value of the state *Vp*(C_i) is the concentration of a given pheromone type p at the city location C_i. Now the difference of pheromone encoding occurs in the following type p at the city location C_i. Now the difference in the pheromone encoding occurs as follows:

- The ant's, strategy as we define
- $(S_i -> A)$ which maps states into action

The particular choice of pheromone to update and to base transition decision is dependent on the ant's internal state.

1. We choose the ant agent, released to search the safe place for the crowd problem with *attractive* pheromone
2. Repulsive pheromone

These ants often select the action putting the pheromone when reaching the 'safe place' and tends to relocate by preferring little intensity of pheromone. If they discover a safe place they keep forcing it and leaving no pheromone. Through this local behavior, the pheromone space is formed in such a way that the gradient of pheromone density is full towards the safe place.

When it reaches the goal, it increases the value on the track it takes and subsequently this safety condition is exchanged, while visiting other crowd; similarly they also adopt certain route and so on. The main steps are presented below:

for each crowd population **do**
if safe place found
then increases edge weights on path to safe place
else if dead end found
then
population stack until a new route towards safe place is found.
Decrease weight of edge corresponds to popped node
else
Select a neighboring node of the current node of movement of crowd
Push this node into the stack
endif
endif
endfor

The modification in the development of ant system has primarily related to modeling the methods of communication among ant agents. Although substantial progresses have been achieved with the crowd algorithm, but transition rule of next iteration for the ants have remained practically unaltered. Ant colony related algorithm show good performance in solving problems that are combinatorial in nature. However some of the real life problems characterized by uncertainty are not covered by any of the modifications of any system that are found in research literature.

In this work, the transition rules for the ant agent incorporated to investigate the crowd movement are modeled using fuzzy if-then rules. Basically the emotion template designated for selfish, angry, sad or confused crowd are presented through fuzzy rule of following type:

If selfish minded crowd is small and sad crowd is less and trail intensity is stronger then volume of confused crowd becomes very small

Therefore to implement the fury transition rule for the flow of the ant agent in war affected region we use following method:

1. The concentration of the trail phenomena c_{ij} on branch i (i=1,2) immediately behind each choice point j (j=1,2) changes in time t according to:

   $Dc_{ij}?D_t = q\ \emptyset_{ij}(t)$ + $q\emptyset_{ij}(t\text{-}\tau)$ - $Vc_{ij}(\tau)$

   with j' = 3 - j

   where:

   $\emptyset_{ij}\ (t)$ represents the overall flow of foragers from the nest to the food source choosing branch i behind the choice point 1, $\emptyset_{12}(t)$ the opposite flow on branch i behind the other choice point j_1= 3 – j= 2, t the average time required for an ant to get from one choice point to the other, q the quality of phenomena laid on the trail and $\surd$ the decay rate of the phenomena. Moreover if the density is low enough,

   $\emptyset_{ij}(t)$ = $\emptyset_j(t)F_{ij}(t)$;

   Where $\emptyset_i$is the outbound flow of foragers from the nest to food source and $\emptyset_2$the opposite nest bound flow. The function F_{ij} describes the relative attractiveness of the trail on branch i at choice point j.

2. The model the pushing of crowd in a panic situation it is important to coordinate the overall flow of ants arriving at choice point j and choosing branch i and the following formula is used:

   $\emptyset_{ij}(t)$ = $\emptyset(t)F_{ij}$[1- *Ya* $\emptyset_{ij}$(*t*- $\tau)/w]$ + $\emptyset$ $(t)F_{ij}(t)$ *Ya* $\emptyset$ $_{ij}$(*t*- τ)$/w$

   Here [$\emptyset_j(t)$ *Fij*(t)] represents the flow of ants engaged on branch i [$\emptyset_j(t), F_{ij}(t)$], diminished by the flow of ants pushed towards the other branch i' by ants arriving from the opposite direction.

   a$\emptyset_{ij}$(*t*-τ)$/w$ is the proportion of ants decelerated by interaction.

   The factor a is proportional to the interaction time period and the lateral width of ants.

   $Y\ \approx$ 0.57 denotes of being pushed in case of crowd encounter.

   The 2nd term on the right hand side of the above equation represents the flow of ants that were engaged on branch i and were pushed towards branch i.

4.2 Details of fuzzy rule based propositions

In order to incorporate the fuzzy rule shown in the model for crowd transition movement through ant agents we assume certain parameters:
$d^k_{ij}-$ the expected distance that k^{th}ant will travel if it decides to go from node i to j .

$\tau_{ij}-$The pheromone trail intensity that the k^{th} ant can smell when traveling between node i and node j.

$w^k_{ij}-$ weight / importance of the k^{th} ant located in node i to visit node j.

Rule 1:

if d_{ij}^k is *small* and τ_{ij} is *weak*

then ants importance/ weight $w_{ij}^k$of visiting j^{th} node is *very high*

else

Rule 2:

if d_{ij}^k is *small* and τ_{ij} is *medium*

then ants importance/ weight d_{ij}^k of visiting j^{th} node is *very high*

else

Rule 3:

if d_{ij}^k is *small* and τ_{ij} is *strong* then ants importance/ weight d_{ij}^k of visiting j^{th} node is *very very high*

else

Rule 4:

if d_{ij}^k is *medium* and τ_{ij} is *weak*

then ants importance/ weight d_{ij}^k of visiting j^{th} node is *low*

else

Rule 5:

if $d_{ij}^k$is *medium* and τ_{ij} is *medium*

then ants importance/ weight d_{ij}^k of visiting j^{th} node is *medium*

else

Rule 6:

if d_{ij}^k is *medium* and τ_{ij} is *strong*

then ants importance/ weight d_{ij}^k of visiting j^{th} node is *high*

4.3 Graphical representation

The network is composed of few cities and their intra connections. The total number of layers in the network, n is equal to the number of transit lines. There is a strong connectivity between two cities where from the movement of crowd begins.

Let the origin of panic crowd 'o' origin and it has to move to safe city, the ants have few options when choosing the first node in the first layer. We model the emotion of ants to be represented through the deposition of new pheromone and at the same time it reflects the propagation from neighboring places.

The attractive pheromone represents the safe state of crowd. As the crowd may alternate between cities, this leads the system into a bi-partite graph. There are 2 shortest paths through this graph from state 10 (C1, 3, 3) to state 11 (C2, 0, 0). So each 11 steps long and differing only the penultimate state (which in this case is safe state of crowd).

In Figure 1 a bipartite graph is described. The war affected crowd alternates in the different city as shown from city 1 to city 2 (can be n cities), So they differ in only penultimate state i.e. {10, 15, 8, 12, 5, 14, 7, 16, 9, 13, 4, 11} and {10, 15, 8, 12, 5, 14, 7, 16, 9, 13, 6, 11}.

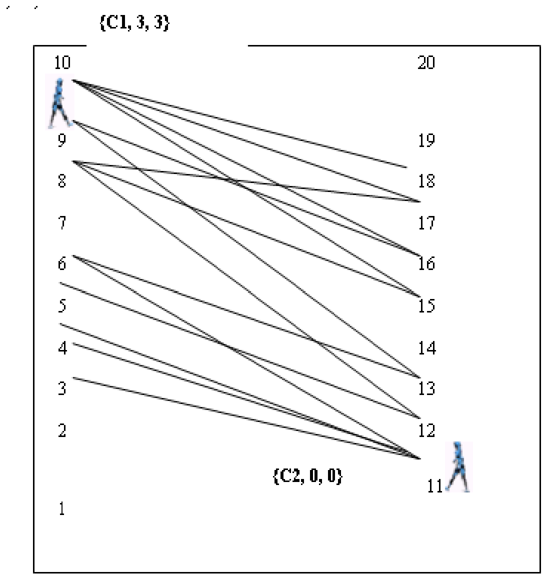

Figure 1. Graphical representation for 20 cities

In our model we follow two different modes:

1. End search safe place mode
2. Start search mode

End search mode simply denotes terminate the run at the point concerning the failure. When starting the search node the ant agent test the trip before they leave any city. If the transmission is not achieving safe place then they cancel the pheromone and for next turn to come. We place the ants with different emotions representing pheromone where the transition rules were controlled using fuzzy-if-then rules.

As base line:

- We consider the entire crowd movement without pheromone (0 bits of pheromone)
- The choice or liking functions return a constant probability
- Afterward agents tries to sense the category of pheromone and category of crowd emotion e.g. Selfish, angry or confused or sad crowd
- From the emotion template of the crowd model presented, we can declare selfish and angry crowd lay down identical (as their output state remains always confused). So an ant agent can know the selfish and angry crowd is present from the pheromone deposition, not the density or population estimation

To sum up these parameters we solicit the model where the dynamics of emotion propagates from one place to the neighboring places. Pheromone will be deposited (irrespective of the current state of crowd that will be clarified further on the basis of their emotion) at every node that was visited at least by one ant agent. Therefore at the beginning of the search process it will be assumed that the pheromone trail is very low in every node and it is equal to some positive constant. But it is not certain what should be the density of crowd in each city at any point of time. In Figure 2 the flow of experiment is presented.

Results of experiment are presented in Table 4.3.

4.4 Synthetic Pheromone

Insects perform impressive feats of coordination without direct inter-agent coordination, by sensing and deposition pheromones in the environment [8]. For example ants construct networks of paths that connect their nests with available food sources.

Mathematically, these networks form spanning trees, minimizing the energy ants expend in bringing food into the nest.

The real world extrapolates three operations on chemical pheromones that support purposive insect actions:

- It aggregates deposits from individual agents
- Pheromone evaporates over time
- It diffuses pheromones to nearby places, thus disseminating information for access by nearby agents.

The pheromone field constructed by the ants in the environment is in fact a potential field that guide their movements. The dynamic field is a measure of agent movement. Agents increment the dynamic field level when moving. By analogy with ant pheromones the dynamic field diffuses and evaporates. By consulting the dynamic field an agent can follow other nearby agents without directly considering the position of any other agent.

Considering these diversified applications of synthetic pheromone, there are different domains applications ([7]). The potential of insect models for multivalent coordination and control thus is receiving significant attention.

Distributed coordination problem is one of the aspects of those applications. Subsequently there are the issues of optimization techniques under the same problem domain. To tackle the uncertainty of search space and constraints there are several techniques proposed ([18], [15], [16]). Hence, the problem of tackling the distribution model of emotion representation of crowd is equally challenging in the light of synthetic pheromone distribution techniques.

The underlying mathematics of the entire search in the war affected region would be:

$S(t+1,p) = E * s(t,p) + r\ (t,p) + q(t,p)$
Where,

- P = $\{p_i\}$ = set of places
- N: $P \quad \rightarrow \quad P$ = neighbor relation between places.
- $S(t,p)$ = pheromone strength at time t and place p
- $r(t,p)$ = external input at time t to place p
- $q(t,p)$ = propagated input at time t to place p
- $E(0,1)$ = Evaporation parameter.

5 Discussions

In the work we specified different pheromone values as indicated the state of mind of the crowd. Typically, 4 types of pheromone representations have been adopted along with no pheromone and smart pheromone (when the different behavioral crowd reach safe place in a war affected region).

Using the proposed model with the smart/attractive pheromone and on the basis of fuzzy rule transition, end search safe place mode succeeds 8940 times, i.e. the crowd is most safe with this choice combining their mental state, 755 with the minimum length and maximum length of 93. The start search safe place mode median is 23.5 with quartile of 18 and 34 respectively.

The improvement over the other types of individual pheromone (e.g. sad pheromone) is (73.5 - 23.5)/ 73.5 = 68%. So it implies that even with a poor initial start which does not exhibits good performance, as more information is available the performance can enhance significantly due to the modification of the different combination of pheromone values of the mental states of the crowd.

This work simply represents bifocal aspects:

1. How to avoid collision among war panic crowd?
2. If the movement of crowd is uncertain then what are the control measures?

The result table calculates the standard statistics and quartile value to evaluate the successful finding of safe state of the crowd using Fuzzy logic based rule and ant colony perspective. This is important as the work also considers non-collision and collision states of crowd depending on the mental state.

6 Conclusion

Study of crowd events is appealing to social simulation researches, because their associated phenomena are largely

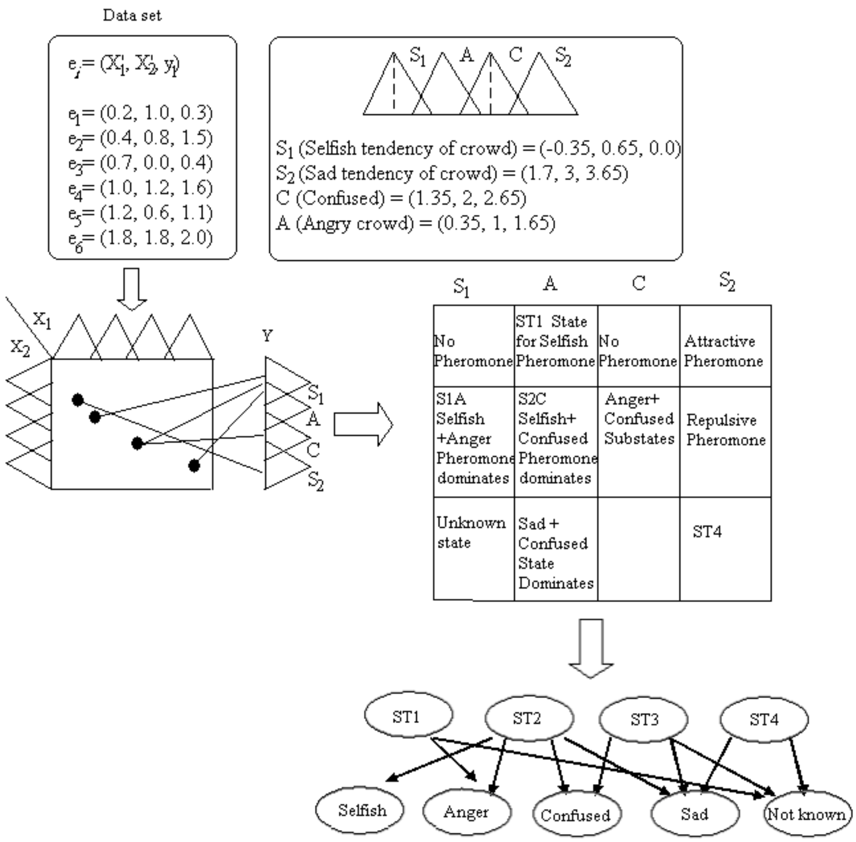

Figure 2. Different state of pheromone with the metal tendency of crowd

emergent in nature. In this paper we create an efficient biologically inspired agent (ant colony model) to analyze emotion model of crowd. An effort is made to simulate the emotional model of crowd using bio-inspired agents and metaheuristic approaches. It is expected that this kind of model would be able to assist substantially in social science, cognitive science and broadly machine like behavior and learning.

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