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AN EXPERIMENTAL STUDY ON SOCIAL BEHAVIOR OF A BOT IN SWARM : INVESTIGATING COMPETITIVE AND COLLABORATIVE BEHAVIOR OF BOTS USING NATURE INSPIRED BOIDS FLOCKING ALGORITHM

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ABSTRACT

Computation evolves through inspiration from Nature. Every algorithm in the world of computer science is inspired from some physical phenomenon present in the environment. It is the narrow ability of understanding of human being which results in presumption of an algorithm from a natural phenomenon. In this study, we intend to explore the behavioral characteristics of the bots in a swarm. The scenario consists of a goal reaching problem for the swarm. The algorithm that ties the swarm together is nature inspired Boids Algorithm. The focus of the study is to analyze how this algorithm helps in controlling the behavior of bots by varying parameters in order to infer collaboration and competitiveness changes among the bots.

I. INTRODUCTION

Inspiration from nature has been a driving force for many great innovations. In Swarm robotics, the co-operation and control over a group are common goals in widely studied problems. The individual animals in a school of fish or flock of flying birds seem to be organized in well-ordered overall behaviors by some form of intelligent coordination. The 'boid' was developed as a simple computer model that replicates such behavior. Each boid runs the boids algorithm, and the boid collectively exhibits realistic flocking or schooling behavior. Such work has clearly shown that well-ordered overall behavior can be formed by merely local and very simple interaction along elements.

This nature inspired algorithm is one of the most popular algorithms used for swarm based applications such as gaming simulations, data clustering and data visualization. In scenarios, such as team construction and crowd or traffic management requires the analysis of qualities depicted by individuals as it could help in sorting out these problems. In such situations, it is required to identify some of the individuals with high competitive spirit and collaborative abilities so that they can influence the whole group to achieve the goal.

However, in most of the studies, these qualities are not explicitly observed in each individual but the whole group is observed at a time. The purpose to identify each individual for the qualities is beneficial for finding out the leaders to be allotted for the group. This would help in betterment of crowd management and will also lead to designing a subjective model for selection of candidates for a team or group. These qualities can be observed from the behavior of individual in a group, which will lead to selection of individuals for a team without judging an individual separately (as the behavior of a person individually is very different from the behavior of same individual in a group).

In this study, we intend to experimentally study the behavior of kilobots in a goal reaching problem using nature inspired algorithm. In this system, bots are judged individually on the basis of Competition and Collaboration among the bots through experimental simulations. These measures signify that how the bots behavior changes as its interaction changes.

I. LITERATURE REVIEW

In order to deal with the group behavior for analyzing various qualities and characteristics of a swarm, first the issues of navigating the entire robot system are dealt with, having wide variety of researches have taken place. Initially, the entire robotic system is allowed to pass through the sweep line and the vertices of the shape of the regions, basically corresponding to the cells. The planner for the robotic system then tries to figure out the cells which contain the starting and the destination node. The planner determines to find an exhaustive path based on the adjacency graph. But this technique is not very useful in complex environments which involve a large number of calculations [1].

In order to deal with the problems of complicacy and straightforwardness, Potential Field Method is another evolving technique to be used in mobile robots planning. The workspace is entirely structured into a grid of cells which are actually rectangular in shape and then every cell is marked as an obstacle or a non-obstacle according to its given property. Then the next step is to calculate the potential functions for each cell based on the distance of every cell from the destination as well as the starting cell and the cells which are marked as obstacles. Based on these values the optimum points are calculated iteratively which are used to trace the complete path. This technique faces some issues due to local minima and thus did not give accurate results [2].

Another variant to compute a path from the source to destination can be using the Euclidean. This distance is considered to be an objective function. Then the some points near that point are randomly generated. Distances which are less than objective function are selected. Then the minimum value is computed and finally selected as the solution. Then in the next iterations directional path is followed and the process is iteratively repeated until an obstacle is configured [3].

As one of the most vital area of the multi robot system is the capability of large number of robots to work in a cooperative manner. Therefore multi robots have the ability to perform such tasks which a single robot is not capable to perform. In order to have a perfect and effective cooperation communication is the most vital component which engulfs physical and chemical cooperation. Various forms of communication can take place in a multi robot system either through directly by using the physical techniques like either light or signal or sound or wave but chemical method is also applied in nature. Various foraging methodology can be used along with physically virtual pheromone concentration to seek optimum path which is convergent to the destination. The robots utilizes pheromone concentration in order to establish communication with other robots and finally lead to an optimal path [4].

After exploring various techniques to solve the goal reaching problem in a swarm, in this paper Boids Algorithm was chosen for studying the behavior of swarm while in the same problem domain of destination reaching. The reason behind choosing this algorithm for this kind of behavioral study is that it is based upon a set of rules with definite parameters. In the process of playing around these simple rules led this study in the desirable direction, which was further easier to interpret and understand.

III. ARCHITECTURE AND FRAMEWORK

The study is based on Kilobots robots, generally used for swarm behavioral study. Initially, this study uses a nature inspired algorithm to study the flocking behavior.

Kilobots

The Kilobot was revealed by the Harvard University to evaluate the performance of collective algorithms on a large number of robots. Kilobots can be defined as a low cost expansible robot system designed basically for exhibiting cooperative behavior. There prevail a large number of algorithms for handling large flocks of communicating robots to be precisely termed as a swarm. These predefined steps are demarcated to control and coordinate the behaviour and the actions of large number of bots. The performance of these demarcated steps depend on the time taken to accomplish the task, complexity of the solution and the cost involved in the solution.

Thus kilobots were designed to ensure communication among kilos of robots in a coordinative manner. Every robot is convened by an automatic process but they are designed with low cost parts with the basic functionality to operate in a cooperative environment [20].

Kilobots function in swarms to probe the algorithms for the cooperative behavior among the robots. The tasks performed by kilobots can be demarcated as planning a path from a point to other point, formation of various shaped like SOS in case of emergency , motion in a coordinated manner, assembling all the bots at a particular position by self-decision , transportation in a coordinated manner , searching for goal and many more.

Kilobot controller consist of a software technology that can handle multiple robots at the same time. It allows transmitting information with the aid of infrared light in order to send commands to all the robots in a single go by imparting a new program. It can also monitor the switching on and off of the robots as well as the interrupt caused during the execution of program in the robot. These tasks have a scope of operating in an area of one meter diameter. The controllers have the ability to program the bots using the embedded ISP technology. Various functionalities observed in controller are the charging, toggling the displays, activating the sleep mode or the wake up mode, pausing or stopping any action, sending or receiving the messages, running the program and checking the battery voltage.

Due to the unavailability of the Kilobot Controller software in the toolkit of Kilobot and other discrepancies like external sensors cannot be mounted on the same the simulated work on the Kilobots could not be implemented in real time. Therefore this study is only experimental simulation based, but can be extended to practical implementation.

Boids is an artificial life program, developed by Craig Reynolds in 1986, which simulates the flocking behaviour of birds. His paper on this topic was published in 1987 in the proceedings of the ACM SIGGRAPH conference. The name "boid" corresponds to a shortened version of "bird-oid object", which refers to a bird-like object. Its pronunciation evokes that of "bird" in a stereotypical New York accent.

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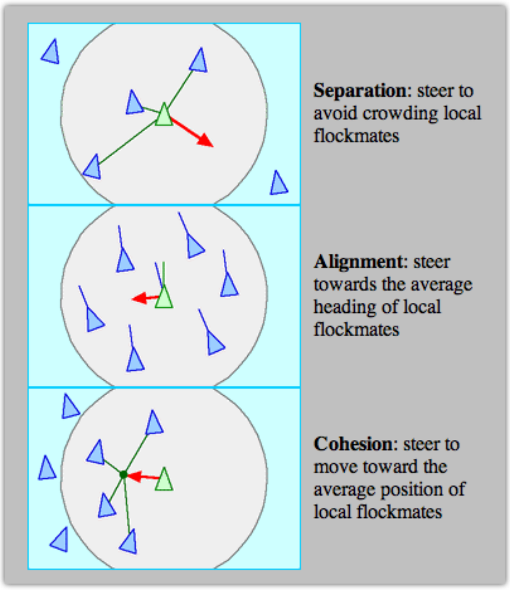
As with most artificial life simulations, Boids is an example of emergent behavior; that is, the complexity of Boids arises from the interaction of individual agents (the boids, in this case) adhering to a set of simple rules. The rules applied in the simplest Boids world are as follows:



IV. COHESION

A flock is defined as a group of boids all staying close to each together, and thecohesion component of the algorithm is mainly responsible for the togetherness aspect of this. Every frame, each boid looks at the position of each other boid to see if it is within a specified NEIGHBOUR_RADIUS, that is, it checks to see which other boids are close enough to be considered flockmates. The positions of the qualifying neighbours are averaged and the boid steers to towards that position. This way, each boid is trying to steer towards the center of the flock, resulting in them all staying close together.

V. ALIGNMENT

Each boid in a flock tries to head in the same direction as the rest of the flock, which is the responsibility of the alignment portion of the algorithm. Each frame, each boid looks at the heading in which it is travelling in comparison to the headings of all its neighbours, and realigns itself to match their heading. The velocity vectors of each boid within the NEIGHBOUR_RADIUS are averaged and the resulting vector points in the average direction of the flock, which the boid then tried to head in.

VI. SEPARATION

While in a flock, each boid tries not to run into each other one in the flock. They try to remain separate by keeping a specified amount of space in between themselves. Each boid checks all the other boids on the map to see if the distance between them is too small, and if so, adds an inversely proportional amount to its velocity in the opposite direction.

The technologies utilized during the implementation of the proposed project are:-

- V-REP Simulator: Robotics simulation platform for Kilobots
- Lua Script: Script used for coding in the simulation platform

6.1 Experimental Setup

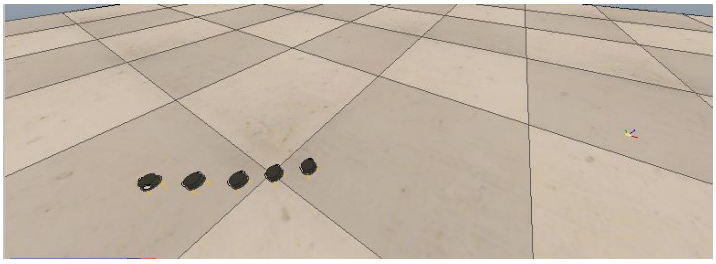
Robot navigation is a scenario which allows robot to infer its position according to the proposed algorithm and then execute the path planning to a particular destination. In Boids algorithm, each boid or bot (in our case) is in motion and has its own velocity. The swarm boids communicate with each other by exchanging the details about what they have discovered through other boids and about dstination.

In this study, the objective is to study the behavioral aspects of a boid in a goal reaching problem using boids algorithm. The experiments are conducted in groups of 5,15 and 30 bots, through a simulation study. In a group there is usually one bot which knows the goal or destination, called as leader bot. The experiments are based on varying parameters of the weights given to three rules of boids algorithm i.e. separation, alignment and cohesion. The positioning of each bot in swarm, their initial velocity and the leaders are all randomly decided upon. The bots communicate with each other by sending messages which contain their x and y coordinates and their unique ID. This unique ID is defined by the user to track the message passing between bots in a swarm. The simulation platform V-Rep provides various mechanisms for message passing, color coding of bots and moving the bot in the space for experimental purposes.

VII. RESULTS AND CONCLUSION

Experiment 1

Collaboration can be easily depicted by the swarm behavior for bots with one leader. In this experiment, a line structure is formed starting with the leader bot. Due to a latch in the simulation platform, message passing between bots take time and till then bots move to a new location, line structure is optimal for study of message hopping between bots. In a simple leader following experiment, hopping of messages from one bot to other is easily visible. This leads to further study and designing of self organizing algorithms for swarms and depicts collaboration as subjective measure.



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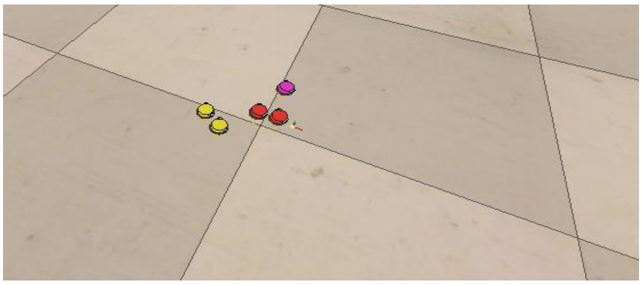

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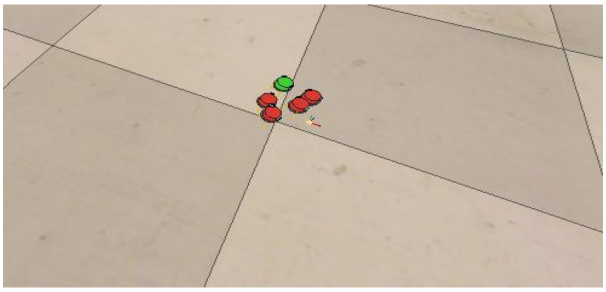

(c)

Figure 2: (a),(b),(c) Represent Movement of bots for Experiment 1

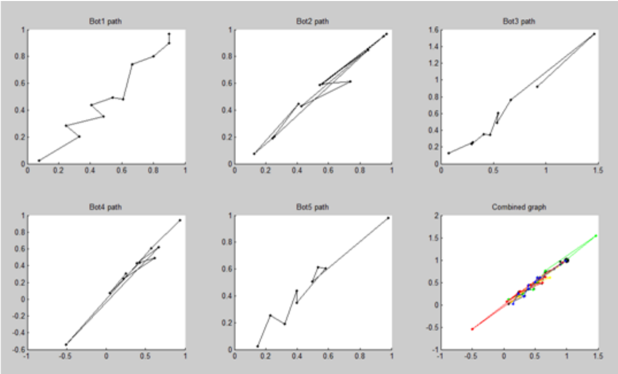

Figure 3: Graph showing path of 5 bots

Experiment 2

This experiment is conducted with a set of 15 and 30 kilobots. The bots are arranged in a swarm formation and only one of them is leader which is placed in the center position of the swarm. Few modifications and their effects are also observed through this experiment such that placing more than one leader in a group say two or three.

First considering only one leader in the swarm, it is observed that if the cohesion parameter is increased, (keeping other two parameters constant) by say 5 points, in the bots close to leader bot then more competitiveness in the bots is seen which are following the leader bot. Practically, by determining the delta value i.e. distance covered by a bot over a certain time, the bots closer to leader bot have higher delta value with respect to the bots far from leader bot. It is observed that initially all the bots move with same pace and same delta value. The basic concept is that, is the bots closer to leader bot will have higher cohesion coefficient, then they will tend to stay close to the leader that they are following. Further, the bots which are not closer to leader bot are calculating their position in relation to other closeby bots, and not directly with the leader bot. In a swarm like structure, the message passes from bot to bot in a message hopping fashion. Thus, if cohesion coefficient of other bots, which are not closer to leader bot, those bots will also tend to maintain close distance with the bots that they are following and hence will show competitiveness.

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Kilobot 1	Kilobot 2	Kilobot 3	Kilobot 4	Kilobot 5	Kilobot 6
0.2349, .1850	0.2349,0.2850	0.2849,0.2350	0.2909,0.2350	0.4499,0.1990	0.4677,0.2500
0.3530,0.2908	0.3532,0.4036	0.3975,0.4352	0.3280,0.3550	0.5563,0.3047	0.5026,0.3513
0.4455,0.4068	0.4457,0.5077	0.4876,0.4511	0.4069,0.4537	0.6021,0.4888	0.5770,0.4321
0.5167,0.4876	0.5180,0.5868	0.5672,0.5249	0.4927,0.5311	0.6555,0.5484	0.6687,0.5287
0.5667,0.5345	0.5736,0.6478	0.6263,0.5987	0.5483,0.5906	0.7689,0.6309	0.7089,0.6783

In the experiment, Kilobot 1 is the leader and Kilobot 2 and Kilobot 3 are closest to kilobot 1 and their weights for parameter cohesion is also increased. The delta value for Kilobot 2 and 3 is relatively higher than for other Kilobots 4,5 and 6.

Delta=distance/time

For Kilobot 2 , delta =0.0453

For Kilobot 4 , delta =0.0371

For Kilobot 3 , delta =0.0426

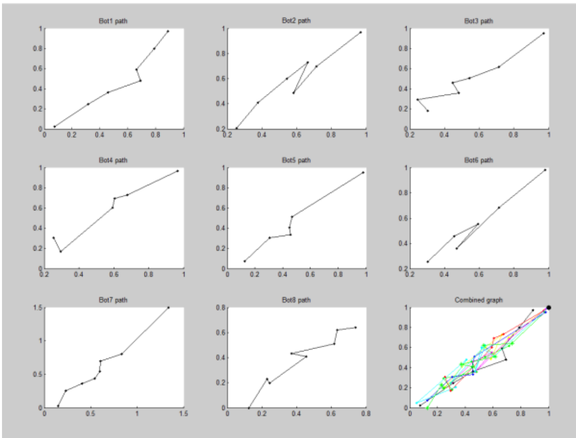
For Kilobot 5, delta =0.0299

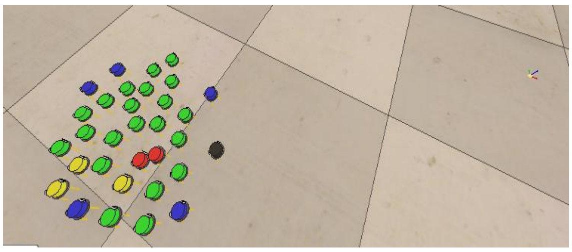
For Kilobot 5 , delta =0.0302

For Kilobot 6 , delta =0.0325

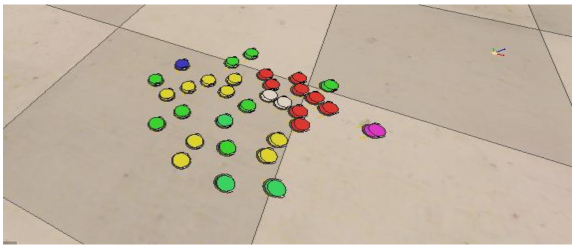
This shows that, the bots with higher cohesion show more competitiveness.

Figure 4: Graph showing path of 5 bots





(a)



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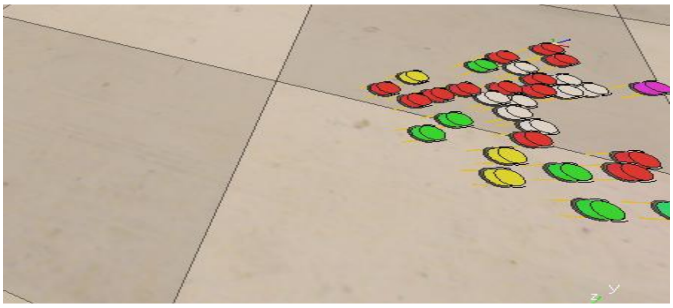
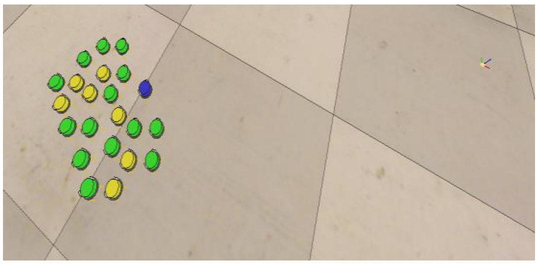


(c)

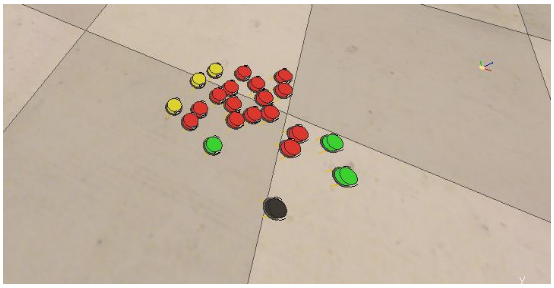
Figure 5: (a),(b),(c) Represent Movement of Bots During Experiment

Experiment 3

This experiment is conducted to analyze result of change in alignment coefficient in the algorithm. Similar to the previous experiment 1, the alignment coefficient of bots is increased. This study shows that the motion of bot depends more on the bot which is moving in the most indifferent direction with respect to the swarm. The rule alignment is used by the individual bot to calculate its average velocity by averaging velocities of all bots it can interact with. This, if the bot it is following is being deviated from the path in order to reach to the destination, then somewhat the bot which is following will also deviate from the path of whole group. This depicts the quality of influence on the bot of its surrounding bots. This further leads to study of crowd mentality in real world.



(a)



(b)

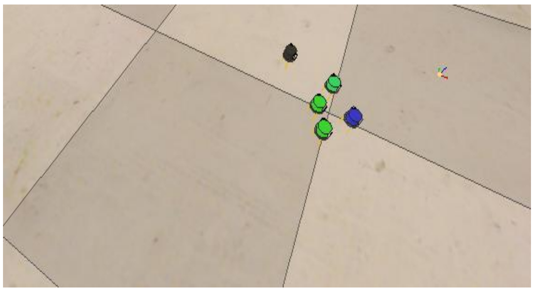
(c)

Figure 6: (a),(b),(c) Represent Movement of Bots During Experiment 3

Experiment 4

This experiment shows that a bot using boids algorithm prefers a group for better results. In this, there is a swarm and a separate bot moving towards the same destination. Initially, the velocity given to lone bot is random and there is one leader in the swarm. Coincidently, the lone bot communicates with one of the swarm bots and becomes a part of the swarm. This in turn shows communication and unity in the swarm. In case the lone bot is not able to get in touch with any of the swarm bots, it moves randomly with its initial velocity and stops only when it gets some message from a still swarm bot.

(a)



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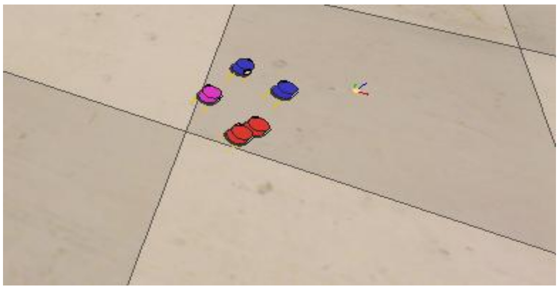

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Figure 7: (a),(b),(c) Represent Movement of bots During Experiment 4

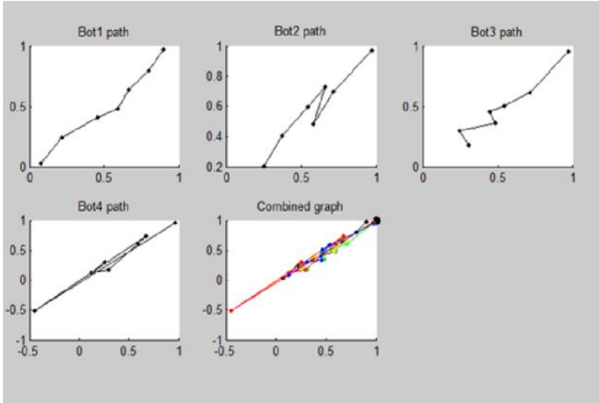

Figure 8: Graph showing path of 5 bots

Due to few limitations of V-Rep , it was seen that there is a delay in message transfer between the bots such that the bot moves to the next position and then its previous position is transmitted or reaches the other bot. Due to this delay, sometimes bots move out of the range of communication and different results are obtained.

VIII. FUTURE WORK

Boids algorithm is an algorithm defined to allow the bots to move from source to destination as well as figuring out an optimal path staying connected to the swarm. But this concept can be extended to implement the self organizing algorithm in parallel as well. Due to the execution of this approach the bots can compute their positions faster and thus can reach the target in a much less time. The basic idea of swarm robotics can be further visualized as a group of bots moving together and carrying some rehabilitation items like the food or medical aid to the disaster affected region. They can also be used to identify the total amount of destruction caused in the mishap region or generate an alarm by creating Emergency SOS shape to inform about the rescue of any victim affected by disaster. They can be employed to wander in the disaster affected region and provide images of the same to determine which areas require immediate help. They are basically put into practice in areas where there is threat to human life either due to landmines or some other mishap so in that case they are of utmost help by saving the human life and speeding up the rescue process.

In scenarios, such as team construction and crowd or traffic management requires the analysis of qualities depicted by individuals as it could help in sorting out these problems. The results from this study can be implemented so that in such situations, it is easy to identify some of the individuals with high competitive spirit and collaborative abilities so that they can influence the whole group to achieve the goal.

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