1. INTRODUCTION

Tackling an emergency situation, in the real world, whenever it arises, is very complex, time consuming and expensive; sometimes it may also involve loss of human lives and resources. Modeling and simulating the situation to find a solution is the only method to overcome all these limitations. Almost all systems in the world can be modeled and simulated. The behavior of a system as it changes over a period of time can be studied by developing a simulation model. Modeling is a suitable tool which plays a vital role in the estimation of data [1]. Thus simulation can be used both as an analytical tool which will forecast the outcome of changes to the existing systems, and as a design tool to predict the performance of systems under different circumstances. Algorithms are step by step procedures which play a vital role in providing solutions to any real world problem, which in turn, can be used for modeling and simulation. Path planning has become an important field of research, investigated by scientists and engineers for a variety of applications. There are plenty of path planning algorithms available in literature for diverse fields. But the present study deals with the path planning algorithms to extinguish forest fires; this has not been discussed so far. In our research work we have modeled and simulated the forest, to find paths for extinguishing forest fires.

Forests are considered to contain potential resources for human beings, animals and the environment. The major hazards to the forests are forest fires. Almost all countries are victims of forest fires, and fires occur every year mostly during the summer season. Nowadays the likelihood of the occurrence of a forest fire is steadily growing because of the change in climate, due to the cutting down of trees in forests for various reasons, such as land for shelter, land for cultivation and killing of dangerous wild animals which pose a threat to human lives. The Forest Survey of India (FSI) reports that the actual forest cover of India is 19.27% of the geographic area, corresponding to 63.3 million hectares. It is also estimated that the proportion of forest areas prone to forest fires annually, ranges from 33% in some states to over 90% in others. The forest fire season in
India is usually from February to mid June of every year. An estimated annual economic loss of ` 400 crore is reported, on account of forest fires in the country. Fire is the most severe natural disturbance affecting the forest ecosystem and diversity, which in turn, produces destructive effects on the landscape. Its impact is felt at every level of the ecosystem [2]. Hence once a forest fire occurs it has to be extinguished as early as possible, because it destroys not only many resources available in the forest, but also affects the environmental and climatic conditions. Since the forest is a very large area, a path has to be found out quickly without collision with obstacles. In this research, we have developed path planning algorithms to extinguish forest fires. Hence, we have chosen a research topic which is of great current interest, social significance and well suited for engineering applications.

1.1 FOREST FIRES

The most common hazard in a forest is the forest fire. It is widely reported that a total of 77,534 wildfires burned 6,790,692 acres in the USA during 2004. Forests fires are as old as the forests themselves. They pose a threat not only to the forest wealth, but also to the entire regime of the fauna and flora, seriously disturbing the bio-diversity and the ecology and environment of a region. During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twigs, which could burst into flames ignited by the slightest spark. Forest fires can be classified into

a. Ground fires
b. Bush fires
c. Crown fires

1.1.1 Ground fires

Ground fires occur when the forest floor and all its decomposing wood, fauna, bacteria and fungi get illuminated. It can burn for months under a snow pack and flare up again in the springtime. Ground fires burn the surface of
the forest floor and remove the soil nutrients. It will take decades for the soil to regain its strength. One of the major concerns about climate change is droughts. Droughts affect the forest floors by drying the soil nutrients, which in turn, makes them more susceptible to ground fires. Sometimes called 'bog fires,' these are slowly spreading, smoldering fires that burn dried, decomposed leaves, twigs, or pine needles that have fallen from the trees to the ground.

1.1.2 Bush fires

Surface fires burn from the top of the forest floor to about 12 feet above the ground. These are fast-moving fires that ignite grass, shrubs, bushes, scrub oak, chaparral, marsh grass (cattails) and grain fields.

1.1.3 Crown fires

When tree tops burn it is called a crown fire, and it's lethal for most trees. Most crown fires are caused by the vertical spread of flames of a brush fire.

1.2 WIRELESS SENSOR AND ACTOR NETWORKS

Wireless Sensor and Actor Networks (WSAN) consist of spatially distributed sensors and actors linked by a wireless medium to perform distributed sensing and acting tasks. In WSANs, the role of the sensors is to gather information from the environment, while the actors collect and process data and perform appropriate actions [3]. WSANs are very much used in habitat and environment monitoring. Sensor nodes can be imagined as small computers in terms of interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors, a communication device and a power source usually in the form of a battery. Sensors are low-cost, low-power, multifunctional devices that communicate untethered in short distances. Actors collect and process sensor data and consequently perform actions on the environment. The propagation of messages
between the hops of the network can be through routing or flooding. In WSANs, the collaborative operation of the sensors enables the distributed sensing of a physical phenomenon. After sensors detect an event that is occurring in the environment, the event data are distributively processed and transmitted to the actors, which gather, process, and eventually reconstruct the event data. The process of establishing data paths between the sensors and actors is referred to as sensor-actor coordination [3]. Once the event has been detected, the actors coordinate to reconstruct it, to estimate its characteristics, and make a collaborative decision on how to perform the action. This process is referred to as actor-actor coordination [4]. As a result, the operation of a WSAN can be thought of as an event-sensing, communication, decision, and acting loop.

1.3 PATH PLANNING ALGORITHM

Path planning is an important task in the field of robotics. Path planning can be defined as “the determination of a path that a robot must take in order to pass over each point in an environment, and the path is a plan of geometric locus of the points in a given space where the robot has to pass through” [5]. Path planning covers a wide area of robotics research, because it enhances moving in both static and dynamic environments. The classification of path planning is shown in Figure 1.3.1. The path planning of a robot depending upon the environment is classified into static path planning and dynamic path planning. Static path planning refers to an environment where there are no moving objects and no obstacles other than the navigating object, while dynamic path planning refers to an environment where all are moving including obstacles. Depending on the algorithm, the path planning is classified as either local or global [5]. Local path planning refers to a robot which has no information about the environment, and global path planning refers to a robot that has information about the environment before it moves towards the target. Depending on its completeness, the path planning is classified as
either exact or heuristic. An exact algorithm finds an optimal solution if one exists, or proves that no feasible solution exists. Heuristic algorithms search for a good quality solution in a shorter time. A path planning algorithm for a mobile robot has two input data in the form of coordinates. The first coordinate is the actual robot position, which is very often referred to as the start coordinate, and the other coordinate is called the target coordinate the robot has to move to. The algorithm must yield as output a possible path between these two points. The apriori knowledge about the environment, in which the robot is supposed to travel, can be classified into

1. Completely known environment
2. Completely unknown environment

The path planning algorithms for the former case, are called path planning with complete information, find-path or piano-mover problem algorithms. In the latter case, it is called path planning with incomplete information or path planning with uncertainty. The information about the environment is represented by the means of a map.

1.4 SCOPE OF THE THESIS
The decomposition of the environment into cells for finding paths has been studied extensively in the literature. Examples of cell decomposition include approximate cell decomposition and exact cell decomposition [6]. Grid based cell decomposition approaches partition the environment into cells of equal area. The other approaches includes topological and hybrid [6]. In this research work, the grid based approach is used for finding paths in the savannah forest to extinguishing fire is investigated. A savannah is a grassland ecosystem characterized by the trees being sufficiently small or widely spaced so that the canopy does not close. The open canopy allows sufficient light to reach the ground to support an unbroken herbaceous layer consisting primarily of grasses. The savannah can be classified into savanna woodland, with trees and shrubs forming a light canopy; tree savanna, with scattered trees and shrubs; shrub savanna, with scattered shrubs, and grass savanna, in which trees and shrubs are generally absent. Other classifications have also been suggested in the literature. The path planning algorithms are developed based on the coordinates. The assumption is coordinate information is available with the sensors and are deployed one in a cell after the decomposition. Since homogenous sensors are used the forest area is decomposed into cells of equal size. Hence grid based approach will be useful. The total area of the forest environment is considered as a grid. This is decomposed into cells of equal area. Each cell will contain one anchor sensor node, which is placed in the centre of the cell. One actor (robot) which knows its location coordinate will be available in the environment to extinguish the fire. The actor will have one processing unit which uses the coordinates obtained from the anchor sensor node as the destination point, and its own coordinate as the source point. Then, using these two points and the path planning algorithm the actor will calculate the path through which it can travel and extinguish the fire. The main subject of this research work focuses on two aspects: (a) Deployment of anchor nodes and (b) Algorithms used by the actor for finding paths.

(a) Deployment of anchor nodes
Nodes can be ordinary nodes or anchor nodes. The anchor node is a sensor node which knows its location based on its deployment. The deployment can be deterministic or non-deterministic. In our research we used the deterministic deployment of anchor nodes. The deployment of nodes is based on following

(i) Quadrant based with entire area divided into four quadrants
(ii) Matrix based coordinates
(iii) Quadrant based with entire area considered as first quadrant
(iv) Integer number

(b) Algorithms used by the actor for finding paths are based on the following:

(i) Trigonometry based path planning algorithm
(ii) Direction based path planning algorithm
(iii) Neural network based path planning algorithm
(iv) Genetic algorithm based path planning algorithm
(v) Line equation using two points based path planning algorithm
(vi) Ant Colony Optimization (ACO) based path planning algorithm

The actor (robot) we have considered is single-point and also multi-point. The motion of the actor is limited to two dimensions.

1.5 RESEARCH OBJECTIVE

The objective of this research work is to design and develop an application based wireless sensor network to detect and determine the direction of path by means of different grid based path finding algorithms and move the actor to the desired place for extinguishing forest fires.
Forest fire detection mechanism using wireless sensor networks have been explored a lot in the literature. But all of them only detect the occurrence of fire and send the message to the server by wireless network. Then based on the information available appropriate actions will be taken by forest department personnel to extinguish fire. There is no information or work regarding how fire personnel or actor will navigate through the forest and extinguish fire. There are plenty of path planning algorithms available in the literature to move an actor or object from source to destination point. In this research the combined idea of detection of fires using wireless sensor network and finding paths using path planning algorithms through which actor or fire personnel can navigate to extinguish fires is explored. The combined idea has not been explored in the literature so far. A novel grid based hybrid path planning approach which uses the combined idea is presented. The path planning algorithms developed in this research are more suitable and efficient in terms of execution time and path cost than the A* algorithm which can find paths to extinguish forest fires.

1.6 OUTLINE OF THE THESIS

The thesis is organized as follows. Chapter 2 deals with the background and literature review of the various path planning methods. Chapter 3 describes the methodology for the research work. Chapter 4 describes the trigonometry based path planning algorithm. Chapter 5 discusses the direction based path planning algorithm. Chapter 6 describes the neural network based path planning algorithm. Chapter 7 explains the genetic algorithm based path planning. Chapter 8 explains the line equation, using the two points based path planning algorithm. Chapter 9 portrays the ant colony optimization based path planning algorithm. Chapter 10 illustrates the results of the comparison of the trigonometry based and line based path planning algorithm with A* algorithm. Chapter 11 concludes the thesis and gives the scope for further work.