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Optimum path detectingalgorithms for sewage water pipeline cleaning mobile bots

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ABSTRACT

The model mobile bots designed to clean dirty are to be planned with the capability to handle multiple environments and multi-range pipelines. The mobile robot node is to be designed with a vision sensor camera and environmental characteristics measuring sensors. The mobile bot node is loaded with cleaning tools to maintain the sewage treatment plants or underground drainage system. The camera image is used to identify the path and ultrasonic sensors are used to sense the exact location and size of blockage. The system also consists of sensor nodes to measure such as the potential of hydrogen(pH), temperature, humidity, electrical conductivity, turbidity, Total Dissolved Solvents (TDS) of sewage water to decide for reuse and retreat.Path detecting algorithms GA, ACO, A* are compared for the best shortest path.

KEYWORDS:path planning, Genetic algorithm, Ant colony algorithm, solid waste management, Sewage water parameters, A* algorithm, best search algorithm, sensors.

1. INTRODUCTION

Manual scavenging of sewage is a huge, problematic, and challenging task. Entering human being into the slabs to clean sewage dirt in the pipe tubes without technical equipment is practiced all over the place.Mobile robots are progressively more used in computerizedmanufacturing environments, planet exploration, surveillance, landmine detection, and other dangerous locations.

Possible usage of mobile bots include a broadchoices such as service robots for elderly and disabledpeoples, programmed automated guided vehicles for transferring goods in a factory, unmanned explode bombremoval robots and planet spaceinvestigation robots. In all these applications, the mobile robots perform their direction-findingresponsibilities as shown in figure 1.

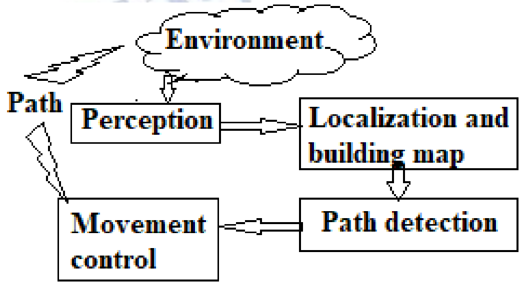

Figure1. Mobile robot navigation task

Direction-finding of a mobile robot involves first step as sensitivity of environment. The next step after sensing the environment is localization and diagramof surrounding called as map building.Cognition and path of lane planning and movement control to reach the destination object is the last step. Perception refers to visual information about the surroundings through camera. The visually sensory dataabout the environment received through camera, and sensors.

Finding posture or structure in the surroundings is localization and map building done through software and sensed data. Forecasting the path to reach target in accordance with the task by using intelligent cognitive decision is an important phase for giving artificial intelligent to robot. Many possible path detection is done before actually completing the preferred route by controlling the movement of the actuators.

Blockage in sewage treatment plants and underground drainage is a common, tedious work in which human usage is not recommended. The world faces a big problem with plastic materials which cause blockage in pipes. The autonomous movement of mobile vehicles reduces human driver error and could reach a place where humans could not work. The cause of vehicle collisions with any object could be avoided in autonomous mobile vehicles by using proper algorithms and sensors to sense the surroundings. These mobile manipulators move from one point to another point safely and effectively. For moving it has to consider the time, distance, energy, shortest path, object structure and many other factors.

The evolutionary optimization algorithms, bio inspired algorithms are computationally efficient and hence are increasingly being used in tandem with classic approaches while handling Non-deterministic Polynomial time hard (NP-hard) problems. This paper discusses challenges involved in developing a computationally efficient path planning algorithm and detecting shortest route to reach the destination. This paper also discusses about the giving intelligent to the robot to take decision about the environment.

1.1 Related work

J.Azeta et al analyzed an [1] Android Based Mobile Robot for Monitoring and Surveillance. Muhammed Jabir et al discussed [2] the wireless control of pick and place robotic arm using an android application. Dr. Rajesh Kanna et al analyzed the [3] intelligent Vision-Based Mobile Robot for Pipe Line Inspection and Cleaning. DS Dixit and MS Dhayagonde discussed the [4] design and implementation of an e-surveillance robot for video monitoring and living body detection. T.B. Bhondve et al analyzed the [5] mobile rescue Robot for Human body detection in the rescue operation of disaster.

Daniel Foeadaet.al[7] discussed about a systematic literature review of A* path finding.Silvester Dian Handy Permana et.al [8] analysed the comparative analysis of pathfinding algorithms A*, Dijkstra, and BFS on Maze Runner Game.Gurpreet Singh Shahi et.al [9] discussed about the comparative study on efficient path finding - Algorithms for route planning in smart vehicular networks. Yun Gu Lee [10] was discussed about the novel camera path planning algorithm for real-time video stabilization. Sami Hasan[11] was analyzed about the single-camera computer vision algorithm for robot shortest path estimator using morphological structuring element with variable sizes.JulienPetre was discussed [12] about the real-time navigating crowds: scalable simulation and rendering. Rahulkala [13] was analyzed the fusion of evolutionary algorithms and multi-neuron heuristic search for robotic path planning. Azad Noori and FarzadMoradi [14] were discussed the simulation and comparison of efficiency in pathfinding algorithms in games. T. van Vuren and G. R. M. Jansen [15] were reviewed about the recent developments in path finding algorithms.

1.2 Problem Statement

Manual scavenging is a problem all over the world. In most countries, human cleaning is followed which creates many issues for humans. In most places in India, most of the sewage cleaning work is done by humans. Human life is challenging during the task as per the analysis by the paper The Times of India[6].

2. SYSTEM DESIGN

The system consists of motors for mobility, a gripper arm, and joints to move and crush the blockage, sensors to measure the sewage water parameters, and a camera to identify the path and ultrasonic sensors for blockage location in the instrument to which it is attached during cleaning. It can be implemented anywhere which has different environments. The environment may be space, military, home, hospitals, sewage treatment plants, and drainages. It has sensors to measure CO_2, pH, temperature, and electrical conductivity, ultrasonic and total dissolved solvents. It measures the poisonous gas from the sewage blockage to protect humans.

The electronics board is designed using a camera, sensors, microcontroller for computation, infrared transceiver units, control, driver unit, and power unit. The arm can push the blocking materials or drill them into small pieces or it can forcefully pass the pressurized water or air to flush the block. It is designed in a detachable way.

Figure 2 shows the schematic diagram of the sensor node interface circuit with mobile bot. It consists of the system such as a microcontroller, infrared transmitter and receiver unit, motor, battery or power unit, limit sensor, pH sensor, temperature sensor, Co2 sensor, EC sensor, signal processing, H bridge, and driver circuits, and all other circuits needed to interface. H-Bridge allows the motor to operate in the forward and reverse directions.The working principle is based on the path planning algorithm and threshold value-checking techniques.Figure 3 shows the algorithm to work the mobile bot for forward and reverse direction. The sensors are used to measure environmental parameters such as pH, temperature, and CO_2.

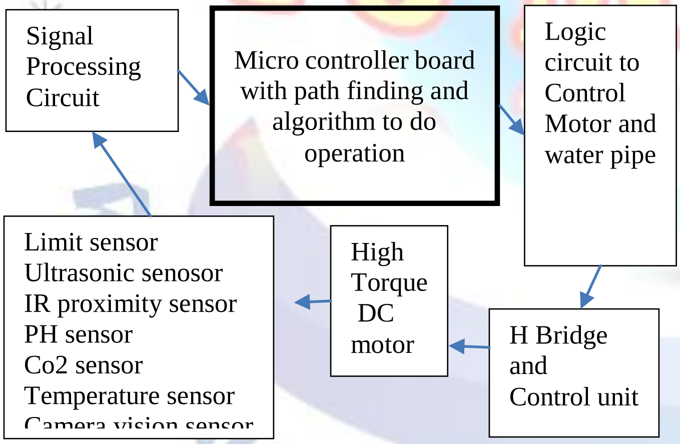

Figure 2. System design for the sensor node to be attached with mobile bot

The sensed values are amplified and compared with the reference threshold values (V_{th}). The infrared sensor and ultrasonic sensors are used to find the distance. If the value is more than V_{th} the motor is switched on for forward or else on for reverse directions. For threshold the value considered are the distance of the object from the actuators, size of the blockage, amount of pressurized water or air required to remove the block and length of the pipeline. We compared these values with the standard values and applied either forward or backward movement of the actuator to destroy the dirt.

The sensed values are compared with the threshold for standard acceptable values. The blockage is removed by passing pressurized water or air. The route is calculated by the best-performing algorithms.

2.1 Path planning

Path detecting of amovable robot is to decide a collision-free shortest best path from ainitial point toa target pointoptimizing a performance points such as distance, timeor energy.If the environment condition is known already or static is off line path planning. Finding the shortest best path for static or known surroundings is the off line path planning. The environment is changeable and could not predict the object in the path known as dynamic or on line path planning. Sewage plant treatment path planning comes in online planning or dynamic nature environment.So the mathematical models shouldincorporate for the dynamic constraints in tough time varying environments such as sewage plant planning.Further, multiple optimization objectives, multiple robotcoordination, uncertainties in sensing, prediction, motion control, etc. pose many other challenges in mobile robotics involved in sewage treatment.

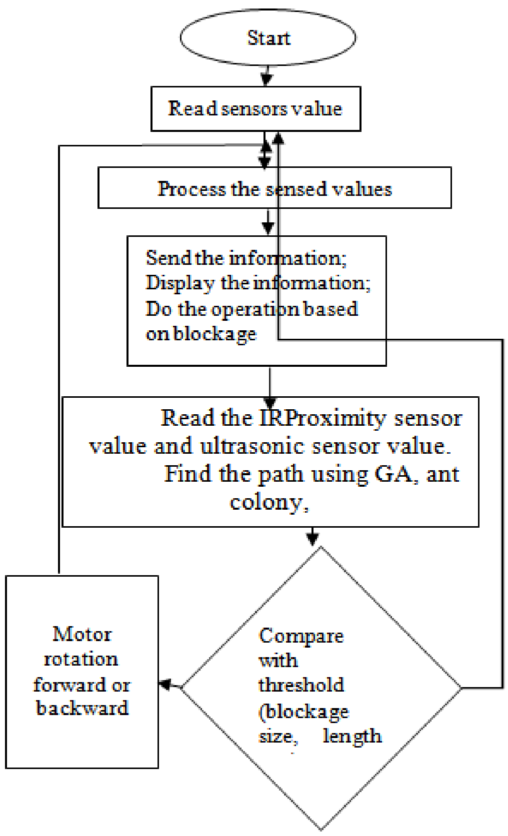

Figure 3. Algorithm for the function of the sensor node

Path planning is an NP-hard problem in case of sewage mobile bots. When system degrees of freedom increase cause the complexity of the problem also increases. The vision sensor camera use a path detecting algorithms such as genetic algorithm, ant colony algorithm, A* algorithm, particle swam algorithms and best search algorithm. All algorithms are compared with each other with various parameters such as shortest route, identifying the path to reach the object, size of the block, collision free path and size of the pipe and pressure require getting the cleaned path. The optimum one is selected to use for identifying safe, efficient, effective, and free of collision and the shortest path to reach the destination to clean any unwanted.

2.2 Genetic algorithm

The genetic algorithm helps in using minimal memory and CPU resources. This is suitable for changing dynamic environments such as treatment plants. It is the method used for a dynamic environment. The genetic algorithm for finding the shortest path is executed in the simulator MATLAB.

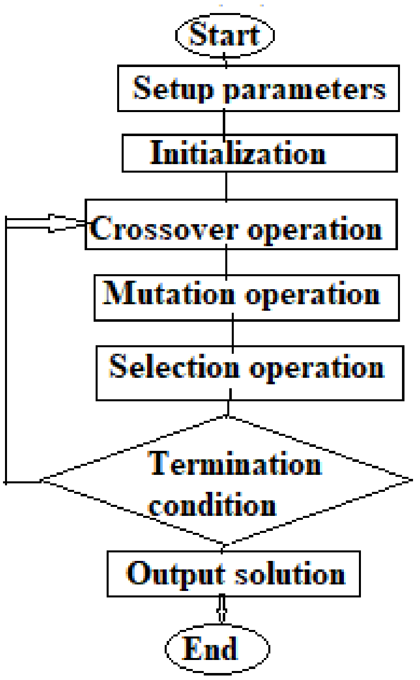

Figure 4 Genetic algorithm steps

Genetic algorithm is a search heuristic based on natural evolution. The offspring inherit the characteristics of parents. Here the best characteristics of parents are inherited to the offspring. The offspring survive the best characteristics of parents are taken as the better fitness. The fitness function considers the shortest, smooth, collision-free path for planning.

$$fitness(o) = distance(o) + smooth(o) + collisionfree(o)$$

Whereas,

$$distance(o) = \sum_{k=0}^{n-1} distance(n)$$

Where n is the distance between two points to move.

$$smooth(o) = \sum_{k=0}^{n-1} e^{a(\theta-\alpha)}$$

Where θ is the angle between two line segments connecting the kth point.α is the expected steering angle and a is the coefficient to move.

$$collisionfree(o) = \sum_{k=0}^{n-1} e(x-\tau)$$

Where x is the smallest distance from the obstacles and τ is the desired distance to reach.The figure 4 shows steps in genetic algorithm.

2.3 Ant colony algorithm

Ant colony algorithm is based on behavior of ant colonies. They find the shortest path for their food. They calculate evaporation rate of their pheromone to find the shortest route to reach the food by travelling various route. The figure 5 shows the principle behind the ant colony algorithm to find the shortest path for their food. The ant colony algorithm is also used to find the shortest and free-from-collision way to reach the destination. Ant releases chemical substances to follow the path.

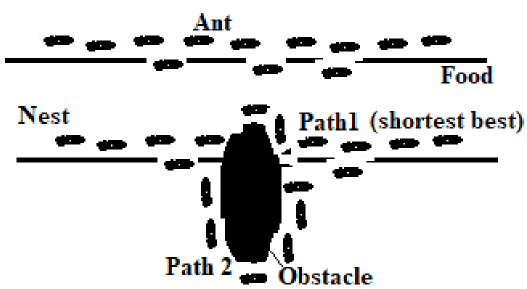

Figure5. Ant colony in finding shortest best path principle for their food search

The chemical substance is higher the following ant chooses that path to follow. As per the algorithm,

$\Upsilon = 0.95\Upsilon(t-1)$.

Where, Υ is the random number generated in 0, 1. ACO can find a better path,even if the complete information of the environment is not known. The convergence speed to reach final answer is slow. ACO takes a lot of computation time.

2.4 Dijkstra, Greedy best algorithms, A*

Dijkstra's algorithm finds the shortest path from the starting point to the goal. This is not recommended because it consumes extra time and resources due to the additional number of details this algorithm inspects for single targets. On the other hand, if there are multiple targets to be searched forthen, thisalgorithm serves as the quickest option.

The Greedy Best-First-Search algorithm also keeps track of a frontier to locate the target. Thisalgorithm makes use of a heuristic function that determines approximately how far from the goal a particular vertex is located. This helps the algorithm to capture the target in its frontier very quickly. Greedy Best-First-Search runs much faster than Dijkstra's algorithm because it uses the heuristic function to estimate the distance to the goal which helps it filter its paths to save time and resources. However, this algorithm, does not guarantee theshortest path. But the path chosen may not be the best one. In dynamic environment such as sewage treatment path detection, these algorithms are not suitable to detect the path.

A* finds the shortest path without fail and it is like Greed Best First Search in that it uses a heuristicfunction to estimate the distance to the goal. This algorithm works extremely well for finding the shortest pathfromoneendpoint to another, but it also litters time and resources on exploring in directions that are not very assuring. The A* algorithm uses both the distances from the start and the approximate distance to the goal toeliminate the limitations of these conventional algorithms.

2.5 Optimization Criteria

Generally speaking, there are many factors that must be considered in the optimization criteriafor planning a mobile path. The commonly used optimization criteria are path length. The path length D is defined as

$$D = \sum_{j=0}^{n=1} \sqrt{(x_{j+1} - x_j)^2 + (y_{j+1} - y_j)^2}$$

Where, $x_j\, and y_j$ are the values of the X coordinate axis and Y coordinate axis of the nodes j, respectively.

To conclude genetic algorithm, gives the shortest path among all other algorithms at a fast response. The efficiency of the algorithm and performance is higher compared with all to find the path in the pipeline for the mobile bots used to clean the pipelines.

3. EXPERIMENTAL RESULT ANALYSIS AND DISCUSSION

The Cleaning mobile bot is attached to thesensing node along with H Bridge DC motor and IR transceiver. The node also interfaced with microcontrollers and sensors pH sensors, temperature, EC, ultrasonic, PIR, and TDS sensors. As the first phase of the project, the sensors are interfaced with the microcontroller and sewage water parameters are measured and analyzed. The second phase of the project is a sensor node with a microcontroller that senses the blockage, finds the route using the best performing-algorithm, and passes highly pressurized water or air to remove the clot. The sensors are interfaced with an interfacing circuit as shown below figure 6.

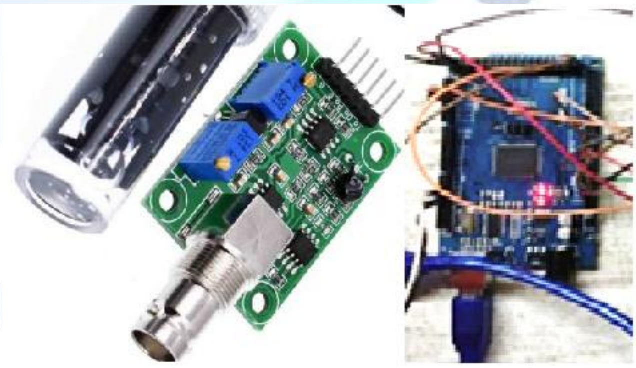

Figure 6.The sensors with node

The microcontroller is easily interfaced with any available cleaning instrument and any other. The motors are smaller and stronger and have a minimum circuit to interface with the mobile bots to operate for cleaning sewage. This designed model of a cleaning mobile bot could do the manipulation of sewage water parameters and mobility with the help of a microcontroller and sensors.Figure 6 shows the node to be used with sensors connected. Actuators such as the DC motor consumes 12 v and 1.2 A. It is connected with the H bridge circuit as shown in figure 7. The driver circuit is implemented in the battery power unit to boost the power. The energy consumed by the motor is very less and operable for a very long time. The DC motor operates in one direction when Q1 and Q4 are operated. The DC motor operates in another direction when Q2 and Q4 are operated. Hence instrument moves either forward or backward direction.

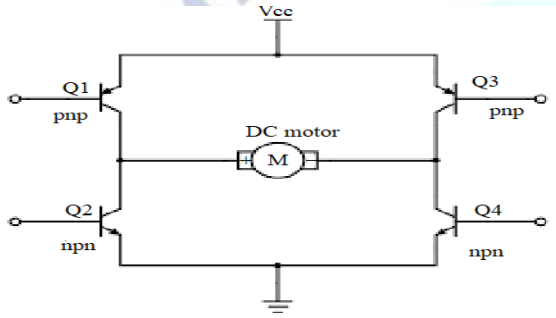

Figure 7. H bridge for DC motor

The table 1 shows the measured sewage water parameters under different locations. The three different locations such as underground drainage, sewage water treatment plant, and pure water storage tank are selected. The pH sensor senses the pH value. EC sensor senses the Electrical conductivity and the TDS sensor senses the total dissolved solvents in the water. The measured values are stored in the memory unit of the microcontroller. It displays the information and sends the information to the owner of the drainage department.

Table 1.The measured pH, EC, and TDS values.

Location	pH	EC(µS/cm)	TDS (ppm)
Under Ground Drainage	6.7	456	2000
Sewage	6.8	327	1600
Water	7	287	150

Table 2 compares the path finding algorithms Genetic algorithm and Ant colony algorithm in MATLAB.

Table2. MATLAB analysis of algorithms.

Technique	GA	AC
Overlapping path	5600m	6700m
Turning number	90	100
Coverage time	10s	20s

Here genetic algorithm and ant colony algorithms are considered and any one of the best methods is implemented in real-time after considering the operating environment and the type of system being used.

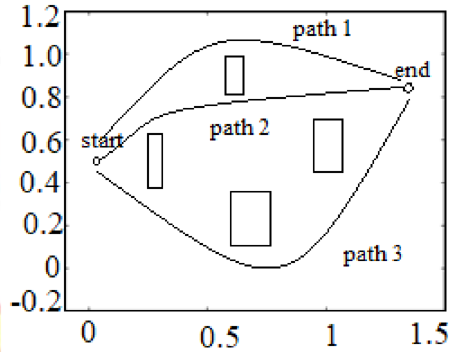

Figure 8. Genetic algorithm output

In an environment such as underground and sewage plants, the environment is rough and tough. It is not a smooth path.

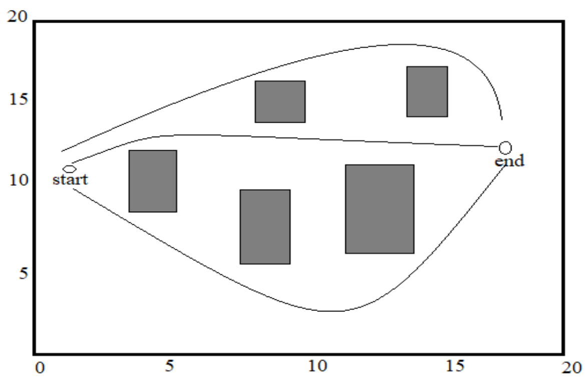

Figure 9. Ant colony algorithm output

The various algorithms are tested before implementation as the environment is very tough to imagine as the environment has static and dynamiccharacteristics.The three paths are suggested and finally, path 2 is selected as the shortest route to reach the destination from the origin. Figure 8 shows the output of the genetic algorithm.Figure 9 shows the output generated using the ant colony algorithm in MATLAB.

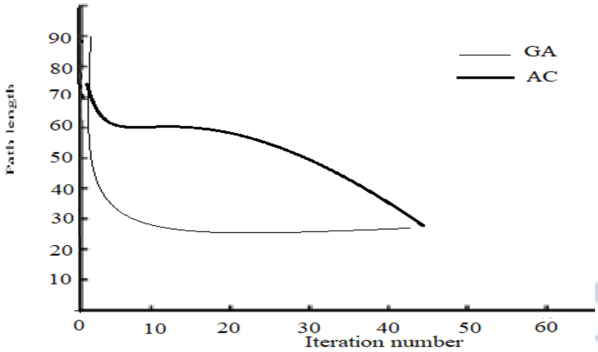

Figure 10. GA and AC comparison

Here, both algorithms are compared to find the path. The genetic algorithm is preferred as it has higher efficiency in finding the shortest route. Figure 10 compares both algorithm and gives solution for shortest best one is genetic algorithm.

4. CONCLUSION AND FUTURE WORK

This prototype mobile bot is used for sewage cleaning. Path planning and sensing water parameters are the additional facilities incorporated in this device. The path planning is tested such as genetic algorithm, A*, Greedy best algorithm, andant colony algorithm. Finally, a genetic algorithm is chosen to find the shortest path. The sensed values are displayed and transmitted. The blockage is removed by passing the pressurized water to the clot. It is planned to enhance the operation by connecting the actuator arm to remove the blockage. It is planned to connect with more sensors. It is planned for doing multi-purpose tasks.

The results shows GA, A*, and ACO are the most used approaches to solve the path planning of mobile robot. Especially twoor more algorithms are combined to improve the quality and efficiency of the solution. Multi-sensorinformation should be adopted for the path planning. Multi-sensor information fusion technology can overcome uncertainty and information incompleteness of the single sensor. It can more accuratelyand comprehensively understand and describe the environment and the measured object.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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