Motion of Multiple Robot in a Curved Boundary & Obstacles

K Prasanna Lakshmi

Abstract:- An attempt is made in this paper to gain the flexibility of movement of robots around the boundary of the workspace, where in many robots are moving at a time in the presence of the static curved obstacles. The boundary of the workspace may be a straight line or curve shaped. The obstacle may be polygonal or curved shaped. A program is developed for the motion of the multiple robots to move from its origin location to the desired location without colliding with the boundary, the other moving robots and the static obstacles. The program is based on the curve fitting technique. As and when the robot comes close to the curved boundary or curved barrier, it will trace the path formed by the curve equation using the technique of curve fitting. Since there are multiple robots, the path planning ensures the robots to reach their targets in minimum time. During tracing the path, if more than one robot is following the same path, priority is assigned to such robots. Multiple robots finds application in assembly operations, medical supplies and meals to patients, disinfecting the rooms for patients etc.

Keywords:- Boundary, Collision, Curve tracing, Obstacles, Priority,

I. INTRODUCTION

The concept of centralized technique makes the robots move in a static environment and the concept of decentralized planning is implemented to move the robots from its initial to final location in dynamic conditions. The static environment is easy to design since the coordinates/locations of obstacles are static and therefore, the path is preplanned following an algorithm which ensures that every robot reaches its destination. The static environment becomes more complicated when any modification is done in the existing workspace. The modification may be due to addition of an extra robot, addition of an extra obstacle and change in the boundary lines or curves. In the decoupled technique, though the program is following a flexible algorithm, where in any change is possible dynamically. Though dynamic change in path planning occurs, it is not ensured whether the robot will reach its destination and sometimes the route may go into a loop, where the whole program need to be stopped abruptly. Some advantages of centralized planning over the decoupled techniques to some extent is globally accepted, but as the number of robot increase along with the static obstacles, the computational effort becomes very tedious and the time the robot takes to reach its destination is not that effective.

Efficiency and completeness are the difference between these two methods. Yet centralized planning gives every robot in the considered workspace a proper and reliable solution to achieve their targets promptly, although it may take a long time. The only advantage the decoupled technique has, that dynamic planning is possible without much computational efforts and can reach the destination in an effective time, but doesn't ensure the reaching point. In this paper, an attempt is made to take the advantages of centralized and decoupled planning so as to reduce the expensive computational steps and ensuring every robot to reach its destination when multiple robots are moving with multiple obstacles with varying shapes. An attempt is made to overcome the problems dealt earlier in the motion of the multiple robots. The task accomplished in making the robot reach its target and the time of reaching the target could be minimized. But since the workspace taken is a limited area during simulation, the number of robots that could be added is also limited. If the workspace can be expanded during simulation, with more robots, the same operations can be carried out well. The location and orientation of the robot's obstacle is recognized by the tactile sensors used in the geometric features of the robot and its surroundings. [5] proposes a plan for collision-free-path of multiple robots with rectangular workspace and polygonal obstacles only. This paper achieves the motion planning for curved obstacles and boundaries. Each motion of the robot with respect to the other robots must be tracked continuously at each moment, so that the robot can make immediate decisions about its route planning and follow the newly designed collision-free path. Though the obstacles are stationary, the moving robot is also treated as obstacle and can be called as moving obstacles. In the real time, the moving obstacles could be the other robots, the automated guided vehicle, the human being, the overhead cranes etc. But the research contribution of this paper is limited to only the geometrical aspects rather than the physical and mechanical aspects. The dynamic properties and the issues related to the mechanical interaction between two physical objects are completely ignored. And therefore the work is purely based on only the geometrical structure.

II. CURVED BOUNDARY & OBSTACLES

For any curve to trace, if various coordinates on the curve are known, an equation of the curve can be obtained by any one curve fitting method. [2] gives a path planner which is the shortest in small local regions using tangent method.

A small change in this paper is proposed in which multiple robots are involved, which might pass through the same path. Newton's divided difference method can be employed to get the equation of the curve of the various known points of the outer boundary of the concerned workspace. The same scheme can be used to find the equation of the boundary of the obstacle if the obstacle forms a curve. The path of the robots are traced in such a way that the work-volume of the robot must not collide with either the boundary of the periphery of the workspace neither the boundary of the obstacle. [3] approach is for the complex polygonal shape. This paper proposes the solution for complex curves. The paths traced are decided on the initial and final location of the robots. The robot may move in forward or backward direction based on the initial and final coordinates of the path. The incremental value in X and Y direction is decided by the following equation :

$$X_{inc} = \frac{ctL - crL}{i} \ ,$$

Where ctL & crL are the terminologies used in the program, defining left position of the target and resource(initial) location respectively,

$$Y_{inc} = \frac{ctT - crT}{X_{inc}}$$

Where ctT & crT are the terminologies used in the program, defining top position of the target and resource(intial) location respectively. [4] shows a curvature path generation methods to make the robots move smoothly and steadily. The approach used in this paper uses a curve fitting method to form the smooth curve. If any robot encounters a curved boundary or a curved obstacle, will follow the generalized equation of newton divided difference interpolation formula.

$f(x) = f(x_0) + (x-x_0) f[x_0,x_1] + (x-x_0) (x-x_1) f[x_0,x_1,x_2]$
$+....+ (x-x_0) (x-x_1)...(x-x_{k-1}) f[x_0,x_1,x_2...x_k]$

One of the equation using newton divided difference method of the boundary of the obstacle is obtained as [6] :
$Y=(0.185x^4 + 2.34 \ x^3 - 20 \ x^2 +183$
One of the equation using newton divided difference method of the boundary of the workspace is obtained as :
$Y=(-0.194 \ x^3) - 8.56 \ x^2 - 1029$

III. PROGRAM & MOTIONS

The present work consist of the following aspects

A. Movement of robots

If the value of X_{inc} is –ve, it will move backward, If the value of X_{inc} is +ve, it will move forward, If the value of Y_{inc} is –ve, it will move downward, If the value of Y_{inc} is +ve, it will move upward. The combination of X_{inc} and Y_{inc} will decide the slope of the robot.

B. Path traced

Once the slope is decided, the path is traced assuming there are no obstacles. Every robot will trace a path of straight line, since the straight line will make the robot to move in

minimum time. In the path specified, on the curve, a last point nearest to the destination is selected. This point is fetched by the intersection of the nearest goal line and tangent. [1] refers to the shortest path among curved obstacles with the help of common tangents.

But if an obstacle stands in the straight line path, an algorithm used, will check for the collision of the moving robot with the boundary of obstacle or the boundary of the workspace.

```
//--Collision Detection or Move--
if((detectCol(lef,top,nrx,nry))!=0)
{if(crpri>nrpri)
{
rbt.setX(nrx+20);
rbt.setY(top-20);
flg=false;
break;
}
}
//--Collision Detection or Move--
```

C. Priority

If more than one robot traces the same path, the robot that has to perform the most important task to be accomplished will be given highest priority. Once the priority is assigned, the deviated path is to be checked for the collision with the boundary of the other robot, workspace and obstacle. The movement of the robot will check the intersection of the (x,y) coordinate of the equation with the (x,y) coordinate of the robot. If the intersection or collision is detected, it will deviate its path and takes an alternate path to go the target location in minimum time.

```
for(int r=0;r<robots.size();r++)
{
        rbt=(Rbot)robots.get(r);
    rbname=((Rbot)robots.get(r)).getName();
        crpri=robots.indexOf(rbt);
//--Priority 0-high
        tp=tgpos.indexOf(rbname);
            tr=(Target)targets.get(tp);
    …..
}
```

For the existing system of workspace, if a robot is added or an obstacle is added, the program will be re-planned dynamically.

IV. TRACING PATHS

Five Robots are considered for an illustration. The Boundary is curved and the obstacles are also curved with some arbitrary directions. The equations of the curves are calculated using the lagrange difference interpolation formula. For avoiding the collisions of the moving robots with the static curved obstacle and curved boundaries, a proper gap is maintained around the obstacles and boundary. All the robots will trace the straight line path and if it encounters an obstacles, will follow a curved path, which is set at a safe offset distance around the obstacles and the workspace.

The offset distance is taken as the size of the robot either vertically or horizontally, whichever is large. The offset distance equal to the size of the robot is taken to ensure that even if the robot enter the offset distance either in upward curve or downward curve, it will not collide with the boundary of the obstacle. The main outer periphery of the obstacle is shown in solid red filled space in the figures mentioned. In the concerned curved workspace, 5 robots with initial and final locations are placed with 3 curved obstacles. The movement of the robots with consequent motions are shown from Fig 1 to Fig. 5.

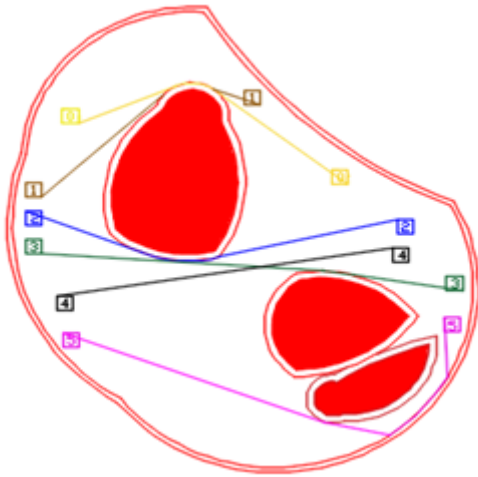**Fig 3: The figure shows the priority is given to Robot**

Fig. 1 The figure shows the initial and final position of the robots with the paths to be traced. The paths are shown in different colors which indicates that the path of each robot is separate.
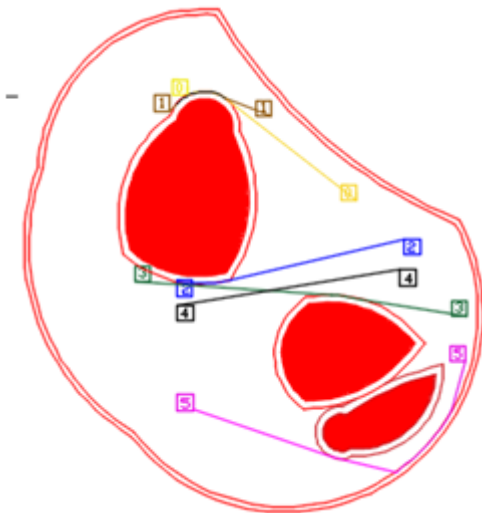

No. 4. Though Robot No. 3 is higher in priority as compared to Robot No. 4.

Fig 2 : The Figure shows the consequent motions of all the robots.

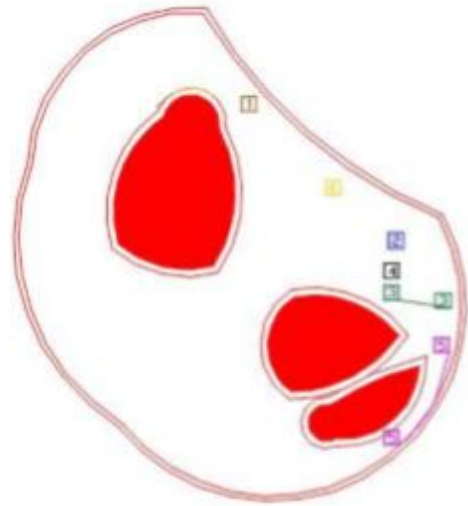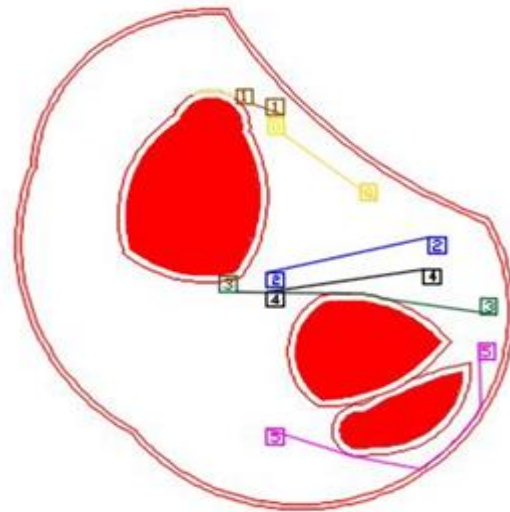**Fig 2. The figure shows the movement of robots giving priority to the lowest no., if following the same path.**
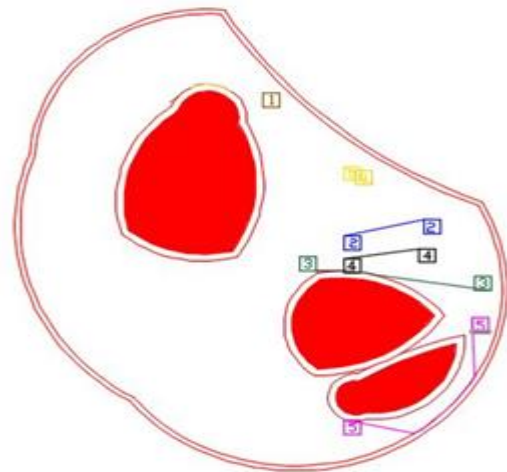

Fig 5: The figure shows that the some robots reached its destination, and some are near to its targets.

V. RESULTS & CONCLUSIONS

The results are obtained for the 5 robots as shown in Figure from Fig 1 to Fig 5. The robots have traced a pre defined path obtained by centralized plan based algorithm. If a robot is added with given initial and final locations, paths are modified in such a way that all the robots reach its destination. The priority is given to the lower index value. Figure 2 indicates that Robot No.2 & Robot No. 3 must obey the same curvature, so Robot No. 2 has priority. So priority constraint decides that Robot No. 2 should move first. Fig. 3 shows even though Robot No. 4 is higher index than Robot No 3, Robot No. 4 moves first. This is due to independency of movement of robots if they are not sharing the same path. Robot No. 3 path was hindered forcefully due to Robot No. 2. While No. 4 was moving on its own path without any hindrance. The robot movement takes place while keeping all such constraints and autonomous movement in control. The obstacles have a peripheral curved boundary placed with a safe offset distance. The robots must drive on this offset curve ensuring avoidance of collision with obstacles and with curved boundaries. Various distances of the motion of the robots with obstacle and without obstacle is shown in table. These distances are in a combination of either completely straight line or a combination of straight line and curve distance as shown in the table.

Table 1: Showing the distance component of various robots

Robot Index No.	Distance with no Obstacle	Alternate Distances with obstacle		Shortest Distance
		1st Possible Path Distance	2nd Possible Path Distance	
0	1069	401+154+656= 1211	485+451+5800= 1516	1211
1	922	635+209+196= 1040	304+451+301+360= 1416	1040
2	1422	475+306+701= 1482	720+209+899= 1828	1482
3	1619	1619	1619	1619
4	1303	1303	1303	1303
5	1463	1070+253+332+251= 1906	928+222+145+248= 1543	1543

Multiple robots movement in a cluttered environment restricted to 2D space is designed in such a way that it does not collide with each other while other robots move. If all such robots moving simultaneously comes across a polygonal obstacle, curved obstacle and curved boundary, it traces the path at an offset distance set by the equation of straight line or equation of the curve. Using the newton divided difference method, the equation of the curve is established. Tracing this curve stops the robot from colliding with obstacles or boundaries. If more than one robot follows the same path, the priority is allocated according to the robot's index No. All the figures shows the motion of the robots in a smooth and safe path, without touching each other or with curved obstacles and boundary.

FUTURE SCOPE

The motion of multiple robots are considered with curved shaped obstacles. But this programming is limited to 2D space and the velocity component is not added to the present parameters. The cluttered environment may include the obstacles hanging from top in 3D space, for which separate programming and experimentation would be appreciated.

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AUTHORS PROFILE

Dr. K Prasanna Lakshmi, Associate Professor in Dept. of Mechanical Engineering. Presently working at JNTUH College of Engineering Manthani. Completed B.Tech (Mechanical Engineering) from NBKRIST in 1997, SVU, M.Tech(Production Engineering) from SVU in 2000, PhD(Motion Planning of Multiple Robots) from JNTU Anantapur in 2011. Publications : 2 National Journals, 3 National Conference, 11 International Journals, 6 International Conferences. Awarded best paper presentation in Nov 2009 in Science Congress Presently guiding 6 PhD scholars. MISTE, AMIE, MIIPE are the existing memberships. Acting as Advisor for IEISC(Institute of Engineers India, Students Chapter, Ramagundam Local Centre).