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P*: A New Path Planning Algorithm for Autonomous Robot in an Unknown Environment

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***Abstract*— In this paper we present P* "P-Star" witch is a new algorithm for sensor based path planning.**

This work is based on PointBug algorithm [11] where we applied some improvements and modifications to overcome some important problems (like infinite loops and the bypass of some sub-paths).

Moreover, we present some simulation results and comparisons with PointBug to evaluate and to verify the performance and the power of the proposed algorithm.

Keywords*— *Mobile Robot, Path Planning, Unknown Environment, PointBug.

I. Introduction

Path planning in an unknown environment is one of the most challenging problems in robotics. A lot of algorithms were proposed for both finding and optimizing the path between two points "source" and "target".

Bug algorithms are based on two behaviors: move toward the target and avoid encountered obstacles. The difference between these algorithms is in leaving conditions [3] [4] [5].

In Bug2 algorithm [1] [2] the robot moves toward the target, when encountering an obstacle the robot follows the boundary of this obstacle, until meeting the line that crosses the start and the target point. After, the robot continues moving toward the target.

Bug2 algorithm weakness was improved by Alg1 [6] and Alg2 [7] [13], which records hit and leave points to avoid tracing the same path twice, with a little differences.

In TangentBug algorithm [8] [9] [10], the robot moves in a straight line toward the target, until encountering an obstacle the robot starts the boundary-following behavior. To do so, TangentBug uses local tangent graph. The robot stops moving along the boundary of the obstacle once it founds a point in tangent graph closer to target than the boundary's point. At that point, the robot continues its path toward the target.

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Dynamic Point Bug algorithm [15] uses another strategy. the robot advances and adjusts its direction continuously to the direction of the target, and when the robot encounters an obstacle it moves to right or left to avoid this obstacle, then it continues its path toward the target.

Another powerful algorithm is PointBug algorithm. Its principle strategy is few different of the others when it introduces the notion of sudden points. As defined in [11], *sudden point* is a point where a sudden change in distance of sensor's range is detected, there is three possible changes: (a) from infinite to some distance in some sides of obstacles, (b) from some distance to infinite distance in other sides of obstacles, (c) from some distance to some distance when an obstacle hides a part of itself or of another obstacle. The first direction of robot is facing the target point where it starts searching for the first sudden point. After, the robot repeats these two actions: (1) Moves towards next sudden point; (2) rotates in the direction of *dmin-line* (the line that crosses the current and the target points) for searching the next sudden point. The robot stops its displacement once it reaches the target or when no sudden points were found. When the robot searches sudden points it ignores sensor reading at rotation of 180° to avoid detecting previous sudden points.

PointBug algorithm is reliable for an environment where there are not many obstacles and no spiral (it may contain one or more simple minimum points), some others reachability limitation are presented in [12] [14].

PointBug algorithm assumes using infinite sensor range witch does not exist in real world.

This paper is organized such as follows: As P* is based on PointBug algorithm, so, in section 2 a set of PointBug's limitations will be presented. In section 3 we describe our new algorithm for sensor based path planning. Finally, a set of experiments will be presented and discussed.

II. PointBug algorithm limitations

PointBug algorithm has several limitations. In this paper we try to overcome its most important problems when we improve this algorithm by applying some modifications and using some new definitions.

As first problem, there are no tests in PointBug algorithm if a sudden point was already treated (since it does not record visited sudden points). This situation can produce infinite loops in case where the target is surrounded by uniform boundary obstacle, see Figure 1.

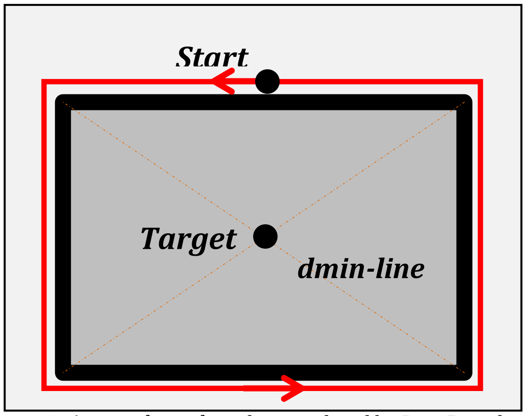

Figure 1: A case of an infinite loop produced by PointBug algorithm.

As second problem of this algorithm is the use of unlimited sensor range. The robot always detects the most far sudden points at first. If there are one or more sudden points closer to the current point they will be detected after. In this case, the robot can bypass some paths that may lead to the target or even miss the alone way to destination, see Figure 2.

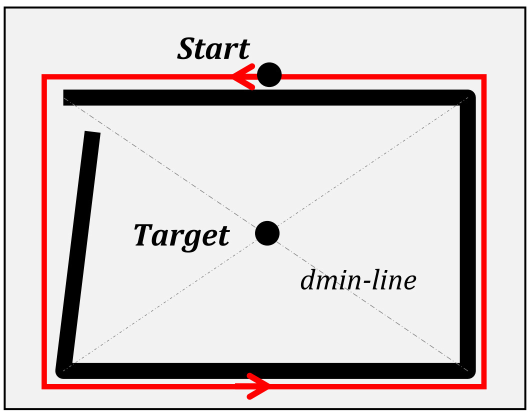

Figure 2: example where PointBug algorithm can not reach the target.

III. Proposed Algorithm P*

As stated previously, a lot of algorithms were proposed for both finding and optimizing a path between two points "source and target". In this work, we propose a new algorithm called "*P* : PStar algorithm*" which is based on PointBug but by providing it some modifications that ensures the resolution of its major limitations.

A. *Solution of endless cycle problem*

In the first part, we propose a solution to the endless cycles and double treatments of sudden points. For this, the condition of 180° bound is removed; the points above 180° will not be ignored. Also, we will record the sudden points and just ignore the sudden points already treated and their sons as well (all their succeeding sudden points). The algorithm follows the same strategy with all points. So, the path generated will be the same as the previous one. As a result the current path will be ignored completely. When the robot finds a treated sudden point once again, it ignores this point and continues the treatment of the succeeding sudden point. If there is no sudden point, the robot return to previous one, until reaching the target or no more sudden point can be found from the first one.

B. *Description of P* algorithm*

Begin

(1) FindNextDirection and advance to selected direction, until one of these events occurs:
(2) The robot reaches the target Stop.
(3) The first sudden point was encountered again and all sudden points were treated: Stop, the target is not reachable.
(4) The robot must respect these rules:
- If no sudden point was found yet treat the first hit point as a sudden point.
- The adjustment of the direction angle must not exceed defined bound value when following obstacle (this bound is a parameter).
- Don't turn back until it's impossible to advance.
- The current sudden point was already treated ignore all its sons (next sudden points detected from it).

(5) If a new sudden point was found, go to (1)

End

FindNextDirection

If No sudden point can found Then /* due to limited sensor range */

The robot tries to move directly as possible towards the target along *dmin-line*, if the robot starts travelling away of target it follows the boundary of the current obstacle

Else

From the current point, the robot numerates all sudden points can found and goes to the first one.

Endif

If the selected sudden point already visited ignore it and go to the next one.

End

IV. Simulation and discussion

In this section we simulate our proposed P* algorithm. The generated robot's trajectories will be compared with PointBug simulations results.

A. *Simulation comparison when no problem of PointBug exists*

Simulation 1: General case

Using limited sensor range gives different results. Moreover, the detected sudden points may differ. The following simulation shows the difference between the results obtained by PointBug algorithm (with unlimited range sensor –as default-) and P* algorithm (with limited range sensor).

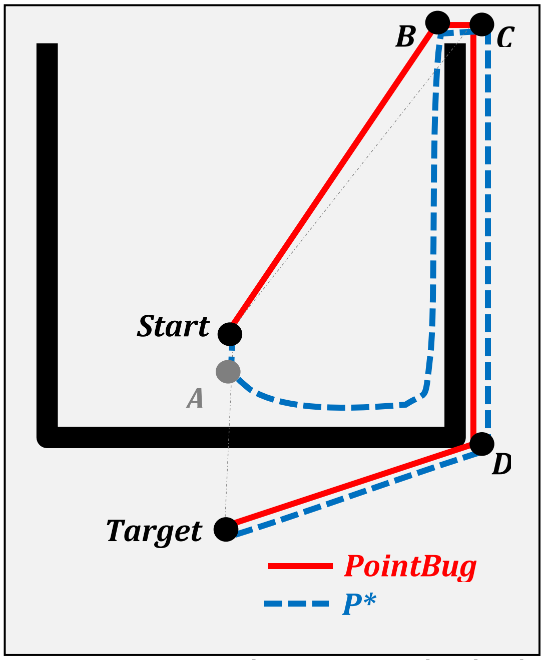

Figure 3: Trajectory generated using PointBug and P* algorithm in a simple Office like Environment (Environment and PointBug trajectory are taken form [3]).

In the case simulated in Figure 3 there are no problems of PointBug algorithm cited in section 2.

In this simulation, we see that the length of the trajectory generated by P* algorithm (dotted curve) converges to the trajectory generated by PointBug algorithm more and more with the augmentation of robot's sensor range.

Simulation 2: When non-straight boundary obstacles encountered

In this case, PointBug algorithm will detect at least one sudden Point, but P* algorithm may not detect any sudden point and the generated path will be better.

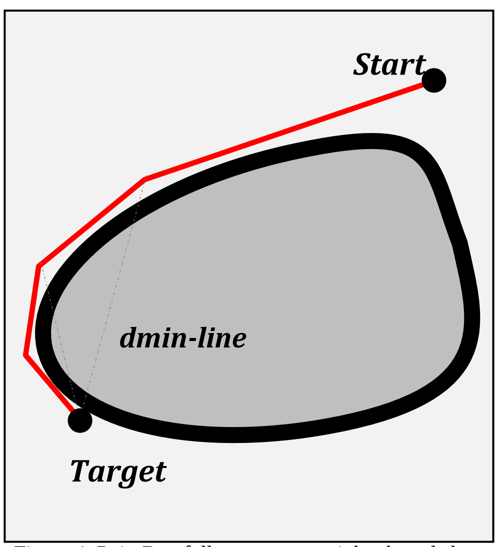

Figure 4: PointBug follows a non-straight obstacle boundary.

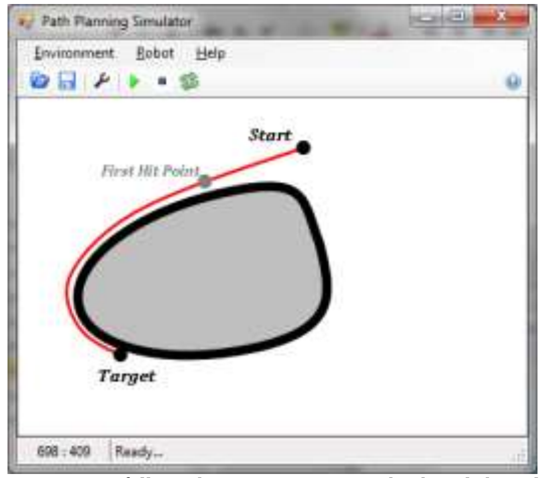

Figure 5: P* follows the previous non-straight obstacle boundary.

Figure 4 shows the trajectory of robot resulting by simulating PointBug algorithm and where three sudden points were detected. Nevertheless, Figure 5 shows the trajectory of the robot when P* algorithm is simulated. In this case we see there are no sudden points and the trajectory is better than that in PointBug algorithm.

The above simulation of Pstar algorithm gives 1138mm vs. 1305mm PointBug's trajectory length.

B. *Simulation when there is a problem of PointBug*

Simulation of bypassing some sub-paths by PointBug

The use of limited range sensor does not necessarily give worse results. Simulation generated in Figure 6 and Figure 7 show a case where the limited range sensor gives a good result while using unlimited range sensor doesn't give a result at all.

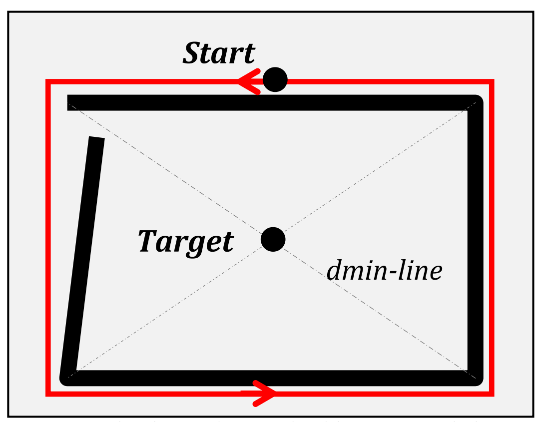

Figure 6: Example where PointBug algorithm can't reach the target.

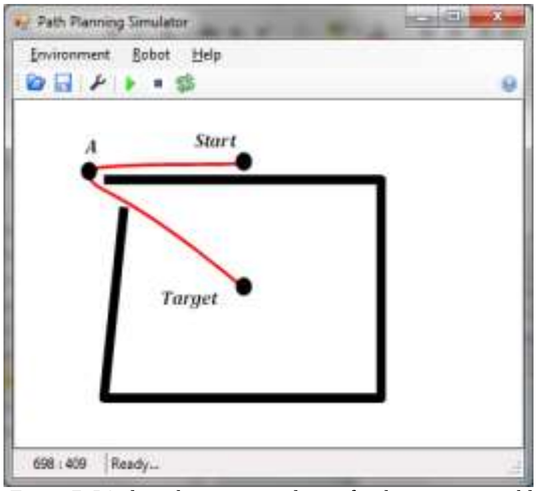

Figure 7: P* algorithm gives a solution for the previous problem.

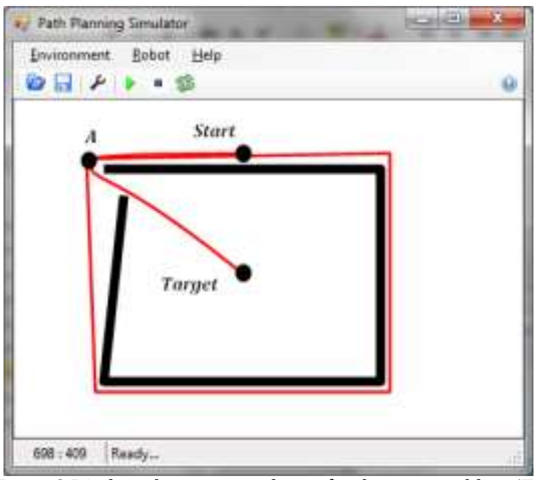

Figure 8 P* algorithm gives a solution for the same problem (**Error! Reference source not found.**) using a limited range sensor (greater distance).

Figure 6 shows the simulation of PointBug algorithm. In this simulation, when the robot reaches the first sudden point, it will detect the one in the opposite corner first. So, instead of going directly toward the target, the robot goes to the opposite corner and continues turning infinitely around it.

Figure 7 shows the simulation of P* algorithm. In this simulation we used a limited range sensor. As result, the next corner will not be detected and the robot goes directly toward target.

In the worst case (example Figure 8), P* algorithm will generate one turn only, because when the robot arrives at the second time to the first sudden point it ignores the next sudden point with its sons and goes toward the target. This case occurs when the ranger sensor is greater than distance between the robot and the most far sudden point.

V. Conclusion

In this paper we presented a new algorithm P*, which can overcome the problems of PointBug algorithm. In the general case and in the absence of the problems of the PointBug algorithm, by increasing the sensor's range the trajectory generated by PointBug algorithm converges to the trajectory generated by P* algorithm. This difference is due to the use of unlimited range sensor by PointBug algorithm.

Another feature of P* algorithm is it can be used directly in a maze without any problem and without changes.

In future, we hope to present an experiment on a real physical environment.

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