Simulation of a Shortest Path using Pixel Method in Robotics Path Planning

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ABSTRACT
This paper presents a technique of designing a wide path motion heuristic path in robots using artificial intelligence. The simulation results show the effectiveness of the method used.

Keywords
Motion heuristics, Wide path motion heuristics, Path Planning, Artificial Intelligence.

1. INTRODUCTION
In the recent days, path planning using Artificial Intelligence has gained a lot of importance. These concepts are being used widely in the field of autonomous agents such as the robots. Wong in [1] presented a heuristic-based motion estimation technique which reduced both the number of search locations (via sub-sampling) as well as the number of operations to perform at each search location (via simplified signature), thus achieving a high speedup factor [1]. Test results showed that quality of the motion vectors found by this heuristic-based technique was close to that of full-search motion vectors [1].

The issue of motion planning for closed-loop mechanisms, such as parallel manipulators or robots, is still an open question. Houssem Abdellatif & Bodo Heimann proposed a novel approach for motion planning of spatial parallel robots in [2]. In this paper, the framework for the geometric modeling was based on the visibility graph methodology. It was opted for a multiple-heuristics approach, where different influences were integrated in a multiplicative way within the heuristic cost function.

Since the issue of singularities was a fundamental one for parallel robots, it was emphasized on the avoidance of such configurations. To include singularity-free planning within the heuristic approach, two heuristic functions were proposed by them, the inverse local dexterity as well as a novel defined "next-singularity" function, in such a way, well conditioned motions can
be provided by a single planning procedure [2].
Paolo Fiorini & Zvi SIIillCr in [3] presented heuristic methods for motion planning in dynamic environments, based on the concept
of Velocity Obstacle (VO).

Two heuristic strategies, viz., selecting the maximum velocity along the line to the target, and selecting the maximum feasible velocity within a specified angle from the straight line to the target were presented [3].

In this paper, we present a method of designing a wide path motion based on motion heuristics techniques. The path uses the concept of graph theory & going in mid-way between the obstacles so that the obstacles are avoided. The paper is organized in the following sequence. Firstly, a brief introduction to the related work was presented in the previous paragraphs. Section 2 gives a in-depth concept on the motion heuristics approach used in the AI techniques. In section 3, the mathematical modeling of the wide path motion heuristic approach is dealt with. Section 4 shows the simulation results. The paper concludes with the conclusions followed by the references.

CONCEPT OF MOTION HEURISTICS

Motion Heuristics is defined as the method of searching an obstacle collision free path in the free work space of the robot from the source to the destination by making use of search techniques such as the graph theory (AND / OR graphs), chain coding techniques and the state space search techniques (best first search, breadth first search) used in Artificial Intelligence [4]. The search techniques used in AI to find the path from the source S to the goal G are called as motion heuristics or the robot problem solving techniques. The word 'heuristic' means to search, what to search ? an obstacle collision free path to search [5].

Holding the object by the gripper $\perp$r to its width and searching for an obstacle collision free path in the work space of the robot from S to G is known as wide path motion heuristics [6]. In this type of motion heuristics method of searching a path, the mobile object / part which is to be held by the gripper is rectangular in shape with a length of L units and width of W units [7]. The object is held by the gripper $\perp$r to its width and the point p of the gripper should match with the center of gravity of the object, like how we hold a duster while rubbing the board.

1. MATHEMATICAL CONCEPTS

Consider the moving / mobile part ABCD to be rectangular in shape as shown in Fig. 1. Let W and L be the width and length of the rectangular mobile part or object and let $W \leq L$. Let P1 and P2 be the two reference points marked on the major axis of the mobile rectangle at a distance of $\frac{L}{4}$ units from each ends and at a distance of $\frac{W}{2}$ units from the parallel side as shown in the Fig. 1 [8].

These two points will always be moving along the GVD path. G is the centre of gravity of the rectangular mobile object. Two reference points are used in order to simplify the wide path motion heuristics. The two reference points are like the front and back wheels of a two wheeler automobile. The front point P2 is advanced incrementally along the GVD path. The back point P1 is found by drawing a GVD circle of radius $\frac{L}{2}$ centered at P2. This circle cuts the major axis of the mobile rectangle ABCD at the point P1. Thus, both the points on the GVD path are obtained [9].

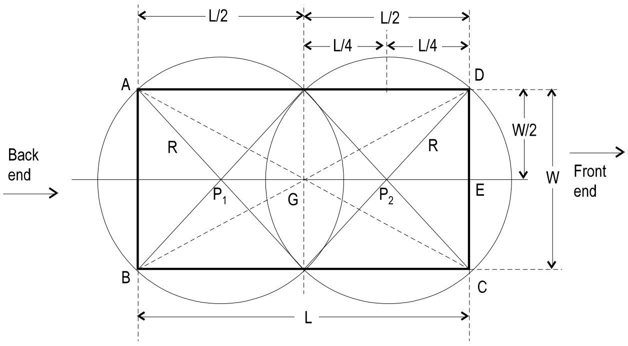

Fig 1. Wide path motion heuristics

A mobile part (Rectangle – ABCD) ;
L → Length ; W → Width ;
P_1, P_2 → Reference points ; G → Centroid ;
R → Radius of GVD circle

Let us determine how the wide path motion heuristics is applicable. Consider two circles ; one with P_1 as center $Radius = R = \sqrt{\left(\frac{W}{2}\right)^2 + \left(\frac{L}{4}\right)^2}^2$ and another circle with P_2 as center [10].

The entire mobile rectangular part is contained within the two overlapping circles. The wide path motion heuristic is therefore attempted when the minimum radius of the chosen GVD path is greater than the radius of either of the circles. i.e., when the radius of the path in between the obstacles is greater than the radius R of the mobile part (of either of the circles on the mobile part), then, there will be sufficient space for the mobile part to move in between the obstacles and as a result of which there will be no collision of the part with the edges of the obstacle [11].

The minimum radii constraint of the chosen path is given by the formula which is derived as follows [13]. Consider any of the circle with either P_1 or P_2 as center. Consider the triangle DP_2E [12].

$$DE = EC = \frac{W}{2} \;;$$

$$P_2E = \frac{1}{4}L = \frac{L}{4}$$

∴, minimum radius [14],

$$P_2D = P_2C = P_1A = P_1B > \sqrt{\left(\frac{W}{2}\right)^2 + \left(\frac{L}{4}\right)^2}$$

$$R > \sqrt{\left(\frac{W}{2}\right)^2 + \left(\frac{L}{4}\right)^2},$$

$$\text{i.e., } R > \left\{\left(\frac{W}{2}\right)^2 + \left(\frac{L}{4}\right)^2\right\}^{1/2} \qquad (1)$$

As long as the space between the obstacles is greater than this minimum radii constraint R as given by the equation (1), then the part will not collide with the obstacle, since it is at [16] a safer distance from the obstacle and clearance exists between the walls of the obstacles and the part [15].

2. WIDE PATH MOTION HEURISTICS

In this section, we present an example of a motion planned with wide path motion heuristics. An example of a motion planned with wide path motion heuristics is shown in the Fig. 2 [17]. The workspace consists of three obstacles ; viz., a rhombus, a triangle, a rectangle inside the robot workspace boundary which is a rectangle. The mobile part is considered as a small rectangle. The mobile part is at source position, S. It has to reach the point G [18].

A shortest path is found out using the GVD techniques and the motion heuristics. The mobile part starts at S, moves along the [19] shortest GVD path as shown in the Fig. 2 in which the center point of the mobile part lies always on the GVD path. Note that translations of the mobile part is performed along the freeways and rotations of the part has to performed [20] at the junction the freeways in order to obtain a smooth motion.

3. SOPHISTICATED WIDE PATH MOTION HEURISTICS

Many a times, ordinary wide path motion heuristics is not sufficient to determine an obstacle collision free path from the source to the destination [21]. In this case, sophisticated wide path motion heuristics comes into the picture as the work space is fully cluttered with obstacles [22]. When the work space is cluttered with obstacles, then sophisticated wide path motion heuristics has to be used. More sophisticated wide path motion heuristic techniques can be applied to the original path if the only available path satisfies R > $\frac{W}{2}$; but, fails to satisfy the [31] minimum radius constraint as given by Eq^n (1) ; i.e., the space in between the obstacles is greater than only half the width of the mobile part [33]. If this is the condition [30]; then, a well designed path has to be planned ; since, there is only minimum space left between the mobile part and the obstacle [23].

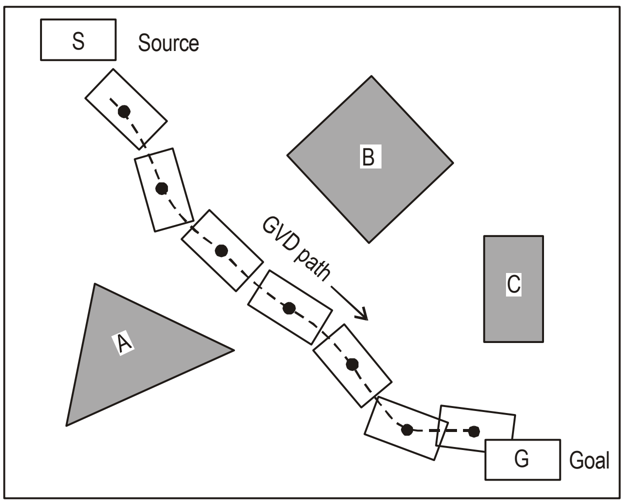

Fig 2. : Wide path motion heuristics

A, B, C - Obstacles ; S - Source ; G – Destination / Goal

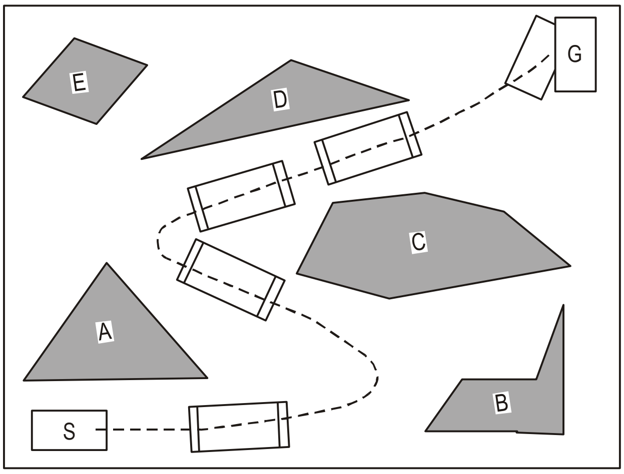

Fig 3: Sophisticated wide path motion heuristics
A, B, C, D, E - Obstacles ;
S, G - Source and goal scene of the mobile part

An example of a path planned in a cluttered workspace using more sophisticated motion heuristics is shown in the Fig. 2. In a cluttered / densely packed obstacle zone, the GVD graph will be a complicated graph and the shortest path consists of a huge number of nodes, arcs and segments [24].

4. SIMULATION EXAMPLE

The best example of an sophisticated wide path motion heuristics can be a real time application, i.e., when a human being is driving his vehicle in a densely packed traffic jam, then he searches a path [32] in the 2D space (i.e., on the road) by moving in between the obstacles, avoiding all the collisions between his vehicular system and the other vehicles which are acting as the obstacles [25].

The human brain which is acting as the computer tries to search for a obstacle collision free GVD path on the road from the source to the destination [28]. Normally, when we are driving our vehicle from the source to the destination, we make use of the GVD technique to move along the desired path [26].

A GUI was developed in C/C++ to simulate the same for an obstacle collision free path in the 2D space with the workspace is cluttered with simple 2D obstacles, say a square [29]. The C/C++ code was run the & the following simulation results were obtained as shown in the Figs. 4 to 6 respectively [27].

5. SIMULATION RESULTS

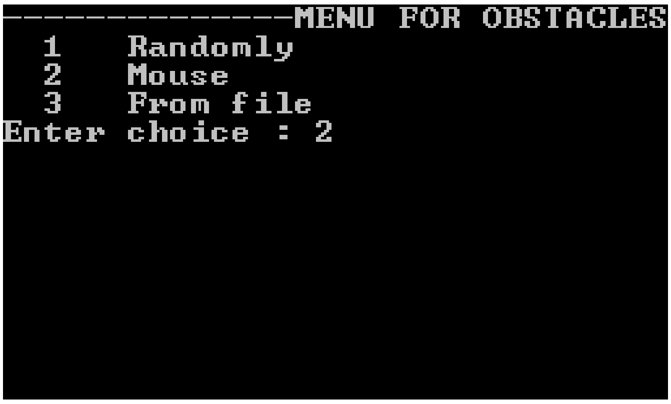

Fig 4 Inputting the parameters

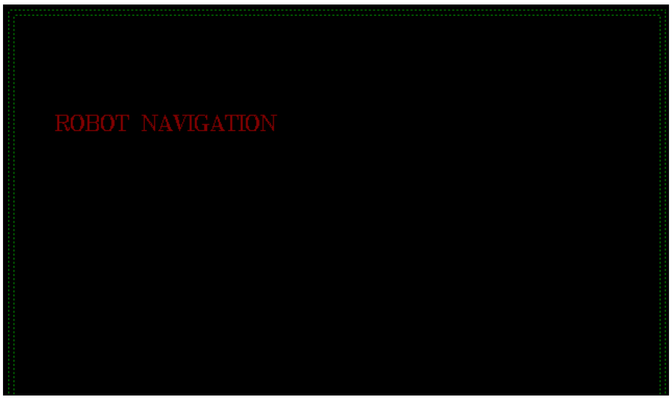

Fig 5 Robot navigation

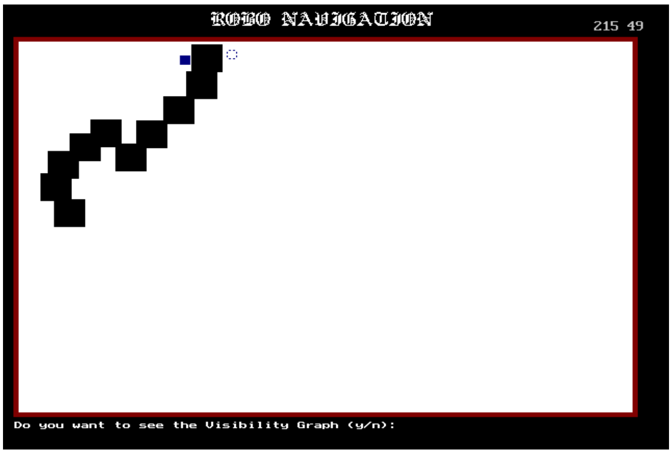

Fig 6 Source

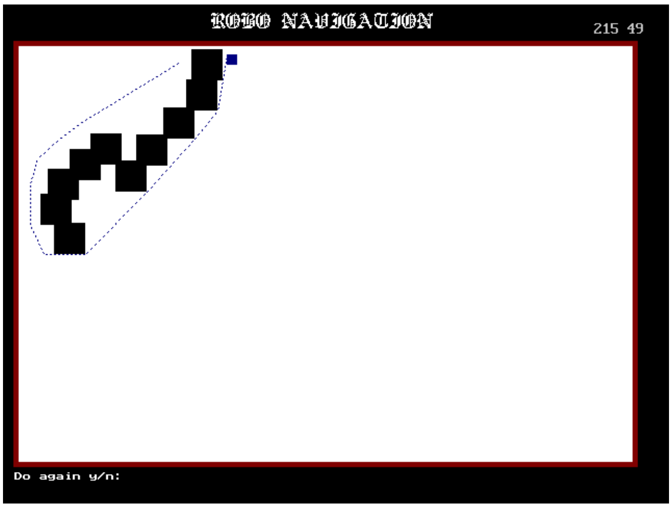

Fig 7. Destination by avoiding the obstacles by moving around them

6. CONCLUSIONS

A brief conceptual design of the wide path motion heuristics was presented in this paper along with the mathematical modeling concepts followed by the simulations. The paper can be further extended to 3 D objects & obstacles in the work space.

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