Asian Resonance

A Study of Robotic Motion Planning

Abstract

Robotic motion planning is one of the threshold area of research in Computer Science and Computational Geometry. More than two thousand papers have been published in the last thirty years. Lozano Perez's contribution to spatial planning that proved Motion Planning is an NP Complete problem. This paper study the Motion Planning through general approaches Road maps such as Visibility Graph, Voronoi Diagram, Subgoal Net works and Heuristic methods In the Heuristic method., a brief out line is given for Probabilistic Road Maps(PRM) in Motion Planning . It also discuss the current trend in Motion Planning such as motion planning for Metamorphic Systems without a fixed base and Visual motion planning in Dynamic environment.

Keywords: Metamorphic System, Probabilistic Road Map, Sub goal Network, Visibility Graph, Voronoi Diagram.

M.G.Mohanan,
Associate Professor,
Department of Mathematics and Computers,
Vivek college,
Mumbai--62

Latha Mohanan
Assistant Professor,
Department of Mathematics and Statistics,
Gurunanak Khalsa college,
Matunga, Mumbai-19

Introduction

The classic path planning problem can be defined as for a given three dimensional rigid body and a known set of obstacles, the task is to find a collision free path from a start configuration to a goal configuration with in a reasonable amount of time. This problem is known as the PIONO MOVER'S PROBLEM. The general approach to this problem is known as THE GENERALISED MOVER'S PROBLEM, ie , the robot as flexible polyhedral with polyhedral obstacles.

The general approaches are Road map ,Cell Decomposition, Potential field, and Mathematical Programming. In the road map approach the free configuration space ,ie the set of feasible motions , retracted, reduced to, or mapped on to a net work of one dimensional lines. The search for the solution limited to the net work and motion planning becomes a graph searching problem. The well known road maps are Visibility Graph, Voronoi Diagram and Sub goal Network. The Visibility Graph is a collection of lines in the free space that connects a feature of an object to that of another .In principle they are the vertices of polygons and there are $O(n^2)$ edges in visibility graph which can be constructed in $O(n^2)$ times and space in two dimensional where n is the number of features.

2 Visibility Recognition Problem(VRP).

Let G = (V,E) be a graph with V = ($v_1, v_2, v_3, \ldots\ldots. v_n$) .The problem of determining ,if there is some polygon P = ($p_1, p_2, p_3, \ldots. p_n$) that has G as its visibility graph is called the visibility recognition problem .Given an undirected graph G with Hamiltonian cycle , the problem of recognising visibility graph is to test whether there exist a simple polygon such that

i) The Hamiltonian cycle of the graph G form the boundary of the simple polygon P .
ii) $v_i v_j \in E$ iff pi , p_j are visible in P.

The different characterisations of visibility recognition for polygon are i) Visibility recognition problem for Spiral polygon is a Perfect Graph which is the Interval graph and the complexity is O(n) times. ii) Visibility recognition problem for Tower Polygon is a Perfect graph which is the Bipartate Permutation Graph and the complexity is O(n) times. Various researchers tried to characterise visibility graphs of simple polygon in different ways as i)S.K Gosh – Visibility graph as Perfect Graphs, circle graph or chordal graph ii) Coullard and Lubin – As by using clique ordering property.iii) Everett and Corneil -- Visibility graph using Minimal Forbidden induced sub graph. iv) Abello and Kumar - Visibility graph using Euclidean shortest path. The VRP for simple polygon is still an unresolved problem as the geometry of the graph is unknown .

3.GeneralisedVoronoi diagram(GVD).[11],[13]

A GVD is the locus of points which are equidistant from two or more obstacle boundaries including the work space boundary. For a polygonal work space populated with polygonal obstacles, the GVD consist of a network of a linear and parabolic line segments. GVD can be computed in O(n log n) where n is the total number of obstacle vertices which was modified with O(n $\log^2$ n)

Subgoal Net Work(Sn)

This method does not build an explicit representation of the configuration obstacles. The list of reachable configuration from the start configuration is mentioned. When the goal configuration is reachable ,the motion planning problem is solved. The reach ability of one configuration from another is decided by a local motion planning algorithm called local operator, such as that moving robot in a straight line between the configurations.

4. Heuristic Methods

The above mentioned classic approaches have many drawbacks, such as high time complexity with high dimensions and degree of freedoms which makes them inefficient . In order to improve the efficiency of classical methods, Probabilistic algorithms have been developed, including Probability Roadmaps(PRM)and Rapidly Exploring Random Tree(RRT), with advantages in high speed implementation. Some of the other methods are Artificial Neural Network, Genetic Algorithms ,Particle Swarm Optimisation, Welvet Theory, Fuzzy Logic etc. Heuristic algorithms do not guarantee to find a solution, but if they do, are likely to do so much faster than deterministic methods.

5. Probabilistic Roadmaps(PRM)

Notations.

Q - is the set of all configuration space a robot can achieve. The dimension of this space is equal to the number of degrees freedom in the robot. For example, a rigid body in 3D has six degree of freedom- three for the position (x,y,z) and three for orientation (rool , yaw ,pitch). QF- is the set of robot configuration that do not intersect with an obstacle. A particular configuration in this space is q. When the degree of freedom of the robot is moderatively large, we approach to heuristic method to solve the problem, one such method is PRM. The principle behind this is that ,. it is cheap to check if a single robot configuration q is in QF or not. The data structure used is a graph G(V,E), The PRM can be divided into two stages as (i)construction stage (ii) query stage.

Roadmap construction

Initially, G := (V,E) is empty. The method begins by sampling the configuration space of the robot by using a Uniform Distribution. If these sample points q are in QF, they are added a nodes to G. The nodes are connected by a local planner P. P(q,qi) return true if there is a collision free path exist between q and qi, else it returns NIL. Collision —free paths are added as edges to G .It is not efficient to try to connect each node with other node in G ,so only the k closest nodes are sent to P.The closest nodes are computed by distance ,metric dt, which can be assumed to be the Euclidean distance. Once this stage is completed, the graph G represents the connectivity of QF.

Query phase

The roadmap constructed can be queried for a path between two arbitrary configurations q int and q goal .It might be possible that multiple paths exists between the two configurations- then shortest path will be selected by algorithms. It is also likely that G does not represent the connectivity of QF that well or no path exist between the two configurations. In that case return to construction stage and add more nodes to the G. The probability of finding path depend on three factors- the length of the known path ,the closeness of the path to obstacles and the number of nodes in the G. The challenging goal would be to extend the method to dynamic scenes. How should a road map computed for a given work space be updated if some obstacles are moving or added? How should the learning and query phase be modified if some obstacles are moving along known trajectories? Answers to this might consist of applying roadmap in the configuration*time space of robots and road map would be a Directed graph.

6.Current Trend In Rmp

i) Motion planning for Metamorphic Systems (without a fixed base)

Modular robotic system consist of a number of identical robotic module that can connect to ,disconnect from, and relocate relative to adjacent modules While individual modules are not capable of moving themselves ,the entire system may be able to re configurated or move to a new position, when it members repeatedly change their position relative to their neighbours, by rotating or sliding around other modules ,or by expansion and contraction. The motion planning for such a system is that of computing a sequence of module motions that bring the system in a given initial configuration into a desired goal configuration G.The upper bound and lower bound on the number of moves for the Motion Planning can be obtained .

ii) Visual Motion planning for Mobile robots

In order to observe the environment, most robots are equipped with different sensors, such as cameras, sonar sensors and tactile sensors etc. Today, many robots are equipped with at least one camera, with examples NOMAD 2000,Sony's AIBO dog-like robots and unmanned BLIMPS and often carry stereo rig. Among all the topics of motion planning , sensor- based motion planning is important for robots because they often work in dynamically changing environment and so must respond to sensory data . In mobile robot systems, sensors are used to detect the obstacles, their existence, distance, shape, size, and motion .In visual motion planning ,generally assume that something is known a priori about the targets and the obstacles, such as location ,shape, size or colour The visual motion planning problem the planning is done in the visual plane ,i.e in the Camera plane. In general, a dynamic control system can be described in state space form as

$x' = F(x(t),u(t),t)$ where $x \in R^m$ is the vector of the system state variable,

$u \in R^p$ denotes the control inputs, and $t \in R$ is the time. The motion of a robot can be transition of the system from x(to) =xO to another x(tf) = xf We can write the constraints of motion planning as $gi\ (x,x',u,t) = 0$, i=1,2 ...., ,lα , $hj\ (x,x',u,t) \leq 0$, j =

1,2,3 .. ,lB where ,lα and ,lB are number of different constrains. Given a robotic system with dynamics in the feature space described by f' = F' (f(t) ,u(t),t) where f, evolution of the features, u = the control input u ∈ R p ,t = time ∈ R and a set of constrains on the robot's motion and the features that need to be satisfied by the robots during the motion ,as well as the initial and final configurations fo and fi ,find a sequence of (piece wise smooth) features

f ' (t) and (piecewise continuous ,bounded) input u ' (t) that satisfy the above equations, minimize the cost function C $=\int_{to}^{tf} L(x,u,t)dt$ and derive the features from f '(0) = f0 (initial position) to f ' (l) = f1 (final goal position).

7) Conclusion.

In this paper we studied motion planning of robots in static and dynamic environment. The static environment ,we have studied Visibility graph ,Voroni Graph and Subgoal Network .The related Visibility Recognition Problem for Simple Polygon is still an unresolved problem. The concept of Visibility graph is restricted to two dimensional space and low degree of freedom .When the dimension increases the visibility graph of motion planning become more complex and inefficient . For the dynamic environment we have studied configuration time space in the PRM.. The Visual motion planning is one of the effective methods for dealing with the motion in dynamic environment on a real time basis and the planning is done in the camera plane.

References:

[1] J. C. Latombe ,Lydia E, Petr S and Mark H. Over mars: Probabilistic road maps for path planning in high dimensional configuration spaces. IEEE Transaction on robotics 'and Autamation vol.12 no.4.Aug 1996.
[2] Adrian Dumitrescu ,Ichiro Suzuki, and Masafumi Y:Motion planning for Metamorphic systems: IEEE Transaction on robotics, and Autamation,vol2O, no 3,june 2004.
[3] G. Chirikjian, A. Pamecha and I. Ebert-Uphoff:Evaluating efficiency of self recognition in a class of modular robots .J.Robotsyst, voll3 ,1996.
[4] JE. Demaine, M. Demaine and H. Verril:Coin moving puzzles, More games of no choice, Cambridge Uni. Press2002.
[5] Hong Zhang, James P. Ostrowski: Visual Motion Planning for Mobile robots :IEEE Trarsaction on robotics and Automation , vol 18,April 2002.
[6] S. Hutchinson ,G .D. Hager and P .1. Corke A Tutorial on visual servo control, IEEE Trans robots ,vol. 12,oct 1996.
[7] Lozano-Perez, T and Wesley, M.A An Algorithms for planning collision free path s among polyhedral obstacle,ACM22, 1979.
[8] C. Taylor,J.P .Ostrowski and S.H. Jung :Robust visual servoing based on relative orientation .IEEE conf. Computer vision and pattern Recognition, June 1999.
[9] J.T. Schwartz and M.Sharir.: On the piano movers problem: General techniques for computing topologici properties of real algebraic manifolds. Advances in Applied Mathematics, 1983.
[10] J. Barraquand and J.C.Latombe: A Monte-Carlo algorithm for path planning with many degree of freedom. IEEE International conf. On robotics and automation. 1979.
[11] Osamu Takahashi and R.J. Schilling: Motion planning in a plane using Generalised Voronoi Diagrams .IEEE Transaction on Robotics and Automation vol 5, no2, April 1989.
[12] S.K. Ghosh ,TIFR ,Mumbai: On recognizing and characterizing visibility graphs of simple polygons. Report JHU E8614, Johns Hopkins Uiiiversity.1986.
[13] Ellips Masehian, and Davoud Sedighizade!' Classical and Huristic approaches in Robot Motion planning. Proceeding s of world Academy of Science ,Engineering and Technology, volume 23 Aug 2007.
[14] Eiichi Yoshida, Claudia Esteves, Igor Belouser, Jean-Paul Laumond Planning 3-D Collision free Dynamic Robotic Motion through Iterative Reshaping. IEEE Robotic Transactions Vol. 24 No.5 Uct 2008.
[15] Motion planning in Dynamic Environment using Velocity Obstacles by P.Fiorini and Z.shiller , International Journal for Robotic Research , Volume 17, Number7 July1998.
[16] J.Canny The complexity of Robot Motion planning , MIIT press Cambridge 1988.
[17] J canny and J . Reif .New lower bound techniques for robot motion planning ,IEEE Symposium on the foundation of computer science ,Los Angels,1987.
[18] F.Kunwar , F. Wong,R Ben Mrad., Guidance based on –line robot motion planning for interception mobile targets in Dynamic Environment, J.of intelligent and Robotic systems,2006.
[19] ICS-AVOID, a Collision Avoidance Scheme for Dynamic Environment : Luis Martinez- Gomez and Thierry Fraichard.ICRA-2009 IEEE International conference on Robotic and automation, Japan, 2009.
[20] Road map – Based Motion Planning in Dynamic Environments Jur P. Van den Berg and Mark H. Overmars.IEEE Transctions on Robotics Volume 21,Number 5, oct 2005.
[21] Vision – based interception of a moving target with a nonholonomic mobile robot . Luigi Freda, Giuseppe Oriolo ,Science Direct ,Robotics and Autonomous systems 55(2007) .
[22] J. C. Latombe, Robotic motion planning Kluwar Academic Publisher Boston 1991.