ISSN 2278 - 3091

International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE), Vol.2 , No.5, Pages : 01-04 (2013)
Special Issue of ICCECT 2013 - Held during September 20, 2013, Bangalore, India

Development of a complex GVD path in 3D space using voronoi diagrams with all types of interactions

Dr. T.C. MANJUNATH, Ph.D. (IIT Bombay), Senior Member-IEEE, Fellow-IETE & IE
Principal, HKBK College of Engineering, S.No. 22/1, Nagawara, Arabic College Post, Bangalore-45, Karnataka.
Email : manjuiitb@yahoo.com Phone : +91 9449820361

Dr. Mala V Patil, B.Tech. (CSE, Karnataka Univ., Dharwad), M.S. (CSE, BITS Pilani), Ph.D. (Anna University)
Professor & Head of the Department, Computer Science & Engineering, HKBK College of Engg., Bangalore-45, Karnataka.
Email : malapatil2002@yahoo.co.in Phone : +91 9886481393

Dr. Rajashekar Patil, B.E., M.Tech., Ph.D (Dr. MGR Univ.)
Asst. Prof., Dept. of CSE, BMSIT, Bangalore, Karnataka, India
Email : rmsvp1@gmail.com Phone : +91 9980335716

Abstract—Task planning is an important problem in robotics. In this paper, we develop a complicated path involving all types of interactions, viz., interaction between a vertex & vertex, edge & a vertex, edge & a edge, thus giving rise to a complex GVD path. A simulation is also done in this regard to show all the 3 types of interactions.

***Keywords* — Robot, Shortest path, Edges, Vertices, GVD.**

INTRODUCTION

Robot actions change one state or configuration of one world into another. For example, there are several labeled blocks lying on a table and are scattered [40]. A robot arm along with a camera system is also there [38]. The task is to pick up these blocks and place them in order [39]. In a majority of the other problems, a mobile robot with a vision system can be used to perform various tasks in a robot environment containing other objects such as to move objects from one place to another ; i.e., doing assembly operations avoiding all the collisions with the obstacles [1]. The paper is organized as follows. With a brief introduction in the previous sentences, Section 2 to 6 gives the interpretation of the design of the obstacle collision free path with various types of interactions along with the mathematical interpretations. Finally, the simulations along with the conclusions are presented in concluding section followed by the references.

INRERPRETATION OF THE DESIGN OF THE OBSTACLE COLLISION FREE PATH

GVD is a method of obtaining a gross motion path from source to the goal by searching all the available free paths in the work space of the robot. The space between the obstacles is referred to as the freeways along which the robot can move. The freeway method of designing the gross motion path is known as the General Voronoi Diagram. Translations are performed along the freeways and rotations are performed at the intersection or the junctions of freeways.

A Generalized Voronoi Diagram or a GVD in free space is defined as *the locus of all the points which are equidistant from two or more than two obstacle boundaries.* If we move along this GVD path, then there will be no collision of the object with the obstacles. The advantages of GVD are the motion is quite smooth, path obtained is the shortest one, object stays well away from the obstacles and avoids collisions, since, it uses the mid way (free way) method. While constructing a GVD, four basic types of interactions of the part / object with the obstacles has to be studied. They are as follows [1] :

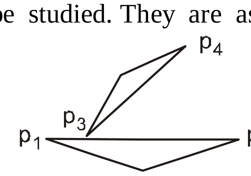

Fig. 1 : Interaction between edges of 2 obstacles

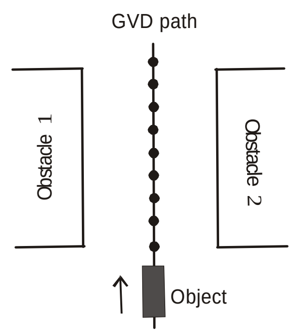

Fig. 2 : GVD path

Simple GVD ' s [1]

(1) First type of interaction - Between a pair of edges.

(2) Second type of interaction - Between a vertex and an edge.

(3) Third type of interaction - Between a pair of vertices.

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(4) Fourth type of interaction - GVD induced by a skew edge.

INTERACTION BETWEEN A PAIR OF EDGES

This is the first basic type of interaction, i.e., interaction between two edges of two obstacles. Consider two edges P_1P_2 and P_3P_4 of two obstacles as shown in the Fig. 3. Here, P_3P_4 is an edge of one obstacle interacting with edge P_1P_2 of another obstacle interacting at the point P_3 [1]

$R \rightarrow$ Radius of the GVD cone.

λ - Be the distance parameter measured along the edge P_1P_2 from P_1.

l_0 - Distance from P_1 to P_3 along P_1P_2.

l_1 - Distance from P_1 to P_5 along P_1P_2.

l_2 - Overall length of P_3P_4.

d - Perpendicular distance from P_4 to P_1P_2.

The radius of the GVD along P_1P_2 can be expressed by a piece-wise linear function of λ and is given by $R(\lambda) = \frac{(\lambda - l_0)\{l_0 - l_1 + \mathbf{sgn}(\lambda - l_0) l_2\}}{d}$, where **sgn** denotes the signum function or the sign of the particular parameter l_2.

If $(\lambda - l_0) < 0$; $\lambda < l_0$, then l_2 is negative, sgn ( ) is minus ;

If $(\lambda - l_0) > 0$; $\lambda > l_0$, then l_2 is +ve, sgn ( ) is positive.

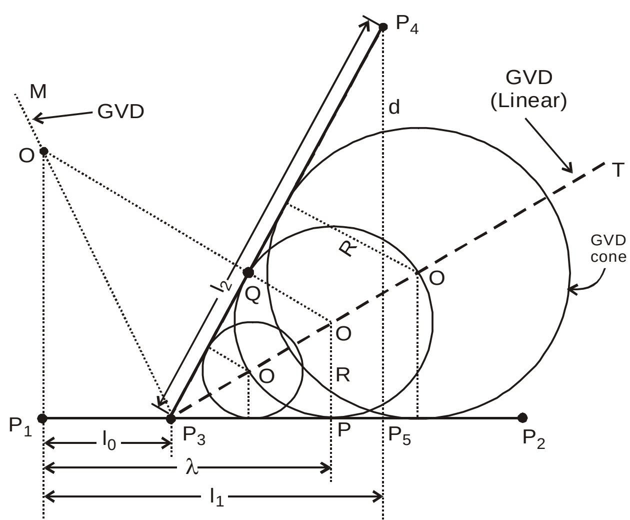

Fig. 3 : Interaction between a pair of edges

Consider a point P at a distance of λ from P_1. Draw a $\perp^r$ line upwards from P. Find the radius of the GVD cone using the formula $R(\lambda)$. Measure the distance along the $\perp^r$ distance. Let it be $PO = R(\lambda)$. With O as center draw a circle to pass through P. Like this, go on finding the centers of the various circles using GVD technique. Join them. We get a straight line. This is the GVD path. Therefore, the interaction between two edges is a straight line, which is the angle bisector. Another GVD path will exist which is $\perp^r$ to the GVD path P_3T and is given by P_3M which is obtained as shown in the Fig. 4 [1].

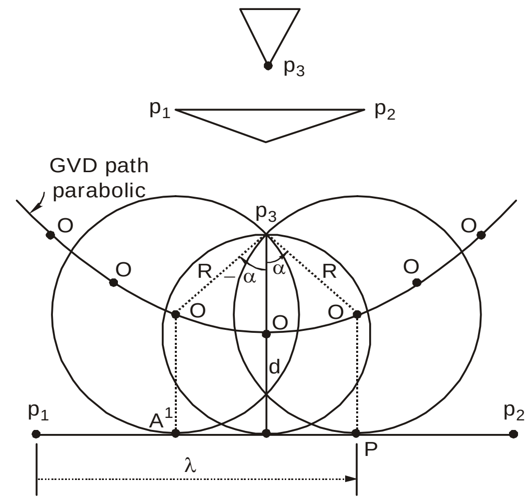

Fig. 4 : Interaction between a vertex P_3 and edge P_1P_2

INTERACTION BETWEEN A VERTEX AND AN EDGE

This is the second basic type of interaction while constructing a GVD between the vertex of an obstacle and an edge of another obstacle as shown in Fig. 4. Here, P_1P_2 is an edge and P_3 is a vertex which is located at a perpendicular distance of d units from the edge P_1P_2. The parameter λ represents the distance along the edge P_1P_2 measured from P_1. The radius of the GVD is given by $R(\lambda) = \frac{d^2 + (\lambda - l_1)^2}{2d}$ or $R(\alpha) = \frac{d}{1 + \cos(\alpha)}$. When $\lambda = l_1$ or $\alpha = 0$; $R(\alpha) = R(\lambda) = \frac{d}{2}$, i.e., midpoint of the perpendicular distance d [1].

Draw a line at an angle of α from the point P_3. Find the radius using the formula $R(\alpha)$. Measure the length of the line as $P_3O = R(\alpha)$. With O as the center and P_3O as radius, draw a circle passing through the point P_3. This circle touches the line P_1P_2 at the point P. Similarly, draw a line at angle of $-\alpha$, get the center of the circle O′ and the point A′. Repeat this for different angles, get the GVD circles, join the center points of all the circles. We get the GVD path [1].

Consider a point P at a distance of λ from P_1. Draw a $\perp^r$ upwards from P. Find the radius of the GVD cone using the formula $R(\lambda)$. Measure this distance R along the $\perp^r$ distance. Let it be $PO = R(\lambda)$. With O as center and PO as radius, draw a circle to pass through P. Like

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this, go on finding the centers of all the various circles. Join them. We get the GVD path. Therefore, the interaction between a vertex and a edge is a parabola.

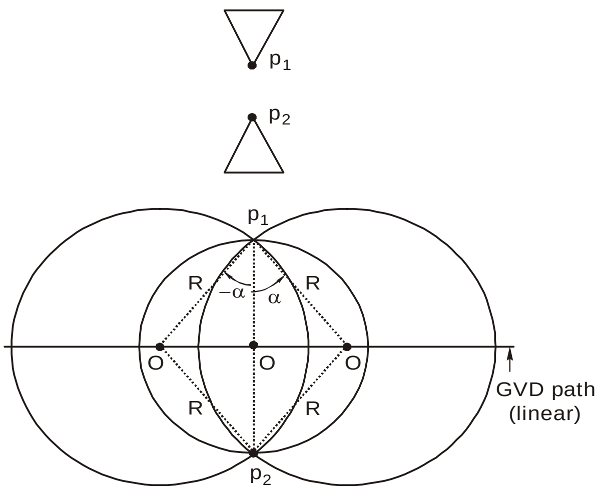

Fig. 5 : Interaction between 2 vertices of obstacles

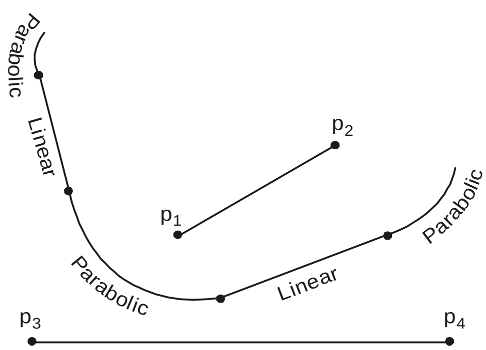

Fig. 6 : A complex GVD

Interaction Between a Pair of Vertices of 2 Obstacles

This is the third basic type of interaction that has to be taken into consideration while constructing the GVD. P_1 and P_2 are two vertices of two obstacles which are separated by a distance of d units as shown in Fig. 5. Draw a line from P_1 or P_2 at an angle of α. Find the radius of the GVD cone using the radius formula $R(\alpha) = \frac{d}{2\cos\alpha}$. Let it be $P_1O = P_2O = R(\alpha)$. With $R(\alpha)$ as radius and O as centre, draw a circle to pass through the points P_1 and P_2. Like this, go on finding the center points of all the circles. Join the center points of all the circles, we get the GVD path. Hence, the interaction between a pair of vertices is a straight line. When $\alpha = 0$, it is $\frac{d}{2}$, i.e., the mid -point [1].

Complex GVD

GVD Induced by a skew edge $\rightarrow$ combination of all the 3 basic types of interactions [1].

In a robotic work cell, there will be a number of obstacles. Hence, the path for the movement of the robot tool from the source to the goal comes across a number of edges and vertices of the different obstacles that comes along the path. Hence, the three types of interactions discussed above will not be sufficient to plan a obstacle collision free path in the 3D Euclidean space. A combination of the above three types of GVD paths is required. Such a diagram obtained is known as *a complex GVD* and is a combination of all the three types of the basic GVD's [1].

For example, consider the problem of finding a GVD path induced by a skew edge P_1P_2 of one obstacle with the second edge P_3P_4 of another obstacle as shown in the Fig. 6. GVD between vertex P_1 and edge P_3P_4 to the left and to the right of P_1 is a parabola. GVD between edge P_1P_2 and edge P_3P_4 to the left and to the right of P_1P_2 is a straight line. GVD between vertex P_2 and edge P_3P_4 to the left and to the right of P_2 is a parabola [1].

Thus, a complex GVD is a combination of linear and parabolic paths. The path will consists of straight line segments and arcs and is also called as *a GVD graph*.

PROBLEM SIMULATION & SIMULATION RESULTS

Consider a workspace cluttered with obstacles, especially triangular obstacles. These triangular obstacles are placed either on the table or on the floor, which is simulated on the computer as a 2D rectangular workspace [22]. Using the mouse or using a rectangular coordinates, we specify the source coordinates (x_1, y_1) [17]. Similarly, using the mouse or using rectangular coordinates, we specify the destination coordinates (x_2, y_2) [18]. A computer algorithm is written using the user-friendly language C++ to find the shortest path using the formula given in Eq. (1). The results of the simulation are shown in the Figs. 5 and 6 respectively [19]. The motion heuristics used in Artificial Intelligence is used to find the shortest path from the source to the goal [21]. Using this motion heuristics, a number of paths are available from the source to the goal, but it selects a shortest path which is the path shown in yellow color in the Fig. 7 [20], [1].

CONCLUSION

A new method of finding an obstacle collision free path from the source to the goal when the workspace is cluttered with obstacles is developed using motion heuristics using an user friendly GUI developed in C++. This method is similar to the method of finding / searching a path by the humans. The method was also implemented on a real time system, say a robot and was successful. Thus, the Artificial Intelligence which uses motion heuristics (search methods) is used to find the obstacle collision free path.

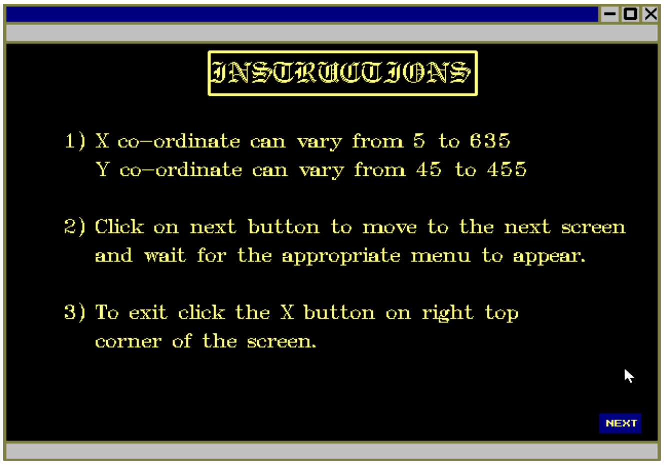

Fig. 7 : Instruction for entering the rectangular coordinates

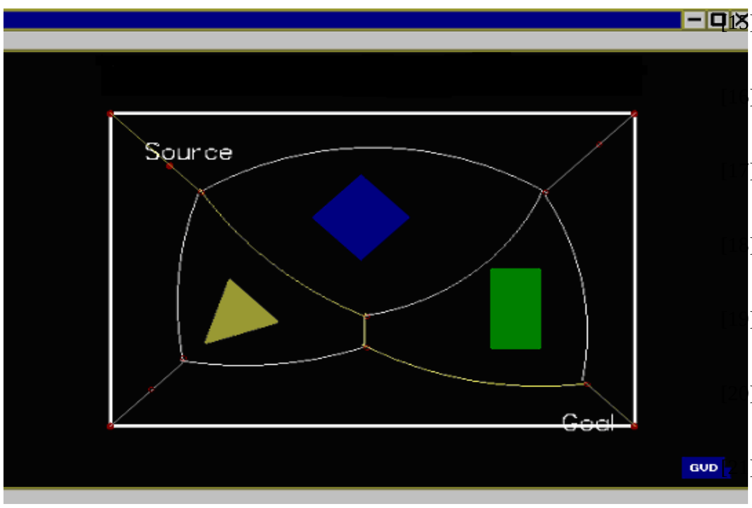

Fig. 8 : Graph showing all the available free paths from S-G

REFERENCES

[1]. Robert, J.S., *Fundamentals of Robotics : Analysis and Control*, PHI, New Delhi., 1992.

[2]. Klafter, Thomas and Negin, *Robotic Engineering*, PHI, New Delhi, 1990.

[3]. Fu, Gonzalez and Lee, *Robotics : Control, Sensing, Vision and Intelligence*, McGraw Hill, Singapore, 1995.

[4]. Ranky, P. G., C. Y. Ho, *Robot Modeling, Control & Applications*, IFS Publishers, Springer, UK., 1998.

[5]. T.C.Manjunath, *Fundamentals of Robotics*, Nandu Publishers, 5th Revised Edition, Mumbai., 2005.

[6]. T.C.Manjunath, *Fast Track To Robotics*, Nandu Publishers, 3rd Edition, Mumbai, 2005.

[7]. Ranky, P. G., C. Y. Ho, *Robot Modeling, Control & Applications*, IFS Publishers, Springer, UK, 2005.

[8]. Groover, Weiss, Nagel and Odrey, *Industrial Robotics*, McGraw Hill, Singapore, 2000.

[9]. William Burns and Janet Evans, *Practical Robotics - Systems, Interfacing, Applications*, Reston Publishing Co., 2000.

[10]. Phillip Coiffette, *Robotics Series*, Volume I to VIII, Kogan Page, London, UK, 1995.

[11]. Luh, C.S.G., M.W. Walker, and R.P.C. Paul, *On-line computational scheme for mechanical manipulators*, Journal of Dynamic Systems, Measurement & Control, Vol. 102, pp. 69-76, 1998.

[12]. Mohsen Shahinpoor, *A Robotic Engineering Text Book*, Harper and Row Publishers, UK.

[13]. Janakiraman, *Robotics and Image Processing*, Tata McGraw Hill.

[14]. Richard A Paul, *Robotic Manipulators*, MIT press, Cambridge.

[15]. Fairhunt, *Computer Vision for Robotic Systems*, New Delhi.

[16]. Yoram Koren, *Robotics for Engineers*, McGraw Hill.

[17]. Bernard Hodges, *Industrial Robotics*, Jaico Publishing House, Mumbai, India.

[18]. Tsuneo Yoshikawa, *Foundations of Robotics : Analysis and Control*, PHI.

[19]. Dr. Jain and Dr. Aggarwal, *Robotics : Principles & Practice*, Khanna Publishers, Delhi.

[20]. Lorenzo and Siciliano, *Modeling and Control of Robotic Manipulators*, McGraw Hill.

[21]. Dr. Amitabha Bhattacharya, *Mechanotronics of Robotics Systems*, Calcutta, 1975.

[22]. S.R. Deb, *Industrial Robotics*, Tata McGraw Hill, New Delhi, India.

[23]. Edward Kafrissen and Mark Stephans, *Industrial Robots and Robotics*, Prentice Hall Inc., Virginia.

[24]. Rex Miller, *Fundamentals of Industrial Robots and Robotics*, PWS Kent Pub Co., Boston.

[25]. Doughlas R Malcom Jr., *Robotics … An introduction*, Breton Publishing Co., Boston.

[26]. Wesseley E Synder, *Industrial Robots : Computer Interfacing and Control*, Prentice Hall.