2012 International Conference on Computer Technology and Science (ICCTS 2012)
IPCSIT vol. 47 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2012.V47.12

DVFH - VFH*: Reliable Obstacle Avoidance for Mobile Robot Navigation Coupled with A*Algorithm Through Fuzzy Logic and Knowledge Based Systems

Srivadhana Siddaiyan [1], Richard William Arokiasamy [2]

[1, 2] Jayalakshmi Institute of Technology

Abstract. A fuzzy approach with a new real-time obstacle avoidance method to the navigation control of mobile robots has been developed and implemented. The problem of driving a mobile robot to a goal in an unknown environment is formulated as a fuzzy logic control problem in which local information is used to make steering and velocity decisions while the robot is moving. This method, named the DVFH * (Double - Vector Field Histogram Enhanced) and coupled with A* search algorithm which is a modified version of earlier Virtual force field (VFF),Vector Field Histogram (VFH) and Double – Vector Field Histogram (DVFH) methods, permits the detection of unknown obstacles and avoids collisions while simultaneously steering the mobile robot towards the target with smooth robot trajectories. A* search algorithm, an optimal path planning algorithm is used to process the efficient traversal of the mobile robot.

Keywords: Fuzzy Logic (FL), The Virtual Force Field (VFF) Method, The Vector Field Histogram (VFH), The Combined Vector Field (CVF) Method, Double-VFH (DVFH) METHOD

1. Introduction

Fuzzy Logic (FL) is used to assist autonomous mobile robot move, learn the environment and reach the desired goal. The fuzzy logic maps the input fuzzy sets representing the mobile robot state space determined by sensor readings to the output fuzzy sets representing mobile robot action space. We propose a system to cope with the problem of autonomous mobile robot navigation with obstacle avoidance and steering towards the target with smooth robot trajectories. It is able to perform path planning and localize the robot in the real world environment. In the earlier methods some of limitations exist via, In VFF algorithm we found that the potential field approach caused oscillations in the presence of obstacles, especially in narrow passages. Poor reliability and not much smoother robot trajectories are found while implementing VHF. Also the oscillation tendency was observed in environments with densely spaced obstacles as it does not consider robot width.

Although the CVF method used only steep force profiles with short-range effects in its VFF components, the oscillation tendency of this potential fields-based method was still observed in environments with densely spaced obstacles. The VFH+ method has its limitation of its local nature, which sometimes leads the mobile robot into dead-ends that could be rectified in our proposed system by introducing local planning into the obstacle avoidance algorithm.

The DVFH method accounts for the rectangular footprint of the robot by calculating simultaneously two vector field histograms centered at two points along the longitudinal axis of the robot, based on the environment information dynamically derived from a ring of 32 ultrasonic sensors. However, the DVFH method provides only one mode of motion with obstacle avoidance, which, in practice, is similar to a follow-the-leader approach. Our proposed system applies A * search shortest path finding algorithm and the enhanced DVFH in order to make the steering and trajectories of the robot along the sideways crabbing or

S.Srivadhana Tel.: + 09942991502 A. Richard William Tel.: + 09894984847 ; fax: +04342246222
E-mail: s.srivadhana@gmail.com, richwill09@gmail.com

diagonal motion. The results obtained from both simulation and actual application confirmed the flexibility and robustness of the robot navigation designed in avoiding obstacles and optimal path finding.

2. Earlier Work

This section will briefly review the earlier methods in order to document the evolution towards the DVFH * method, which is the objective of this paper.

2.1. The Virtual Force Field (Vff) Method

Borenstein and Koren [1989] developed one of the earliest real-time obstacle avoidance methods, called the virtual force field (VFF) method.The VFF method is specifically designed to accommodate and compensate for inaccurate range readings from ultrasonic or other sensors. To do so, the VFF method uses a two-dimensional Cartesian grid, called the histogram grid C, to represent data from ultrasonic (or other) range sensors. Also the VFF method allows to immediately using real-time sensor information to generate repulsive force fields. As the vehicle moves, a square “window” accompanies it, overlying a region of C. We call this region the “active region”, and cells that momentarily belong to the active region are called “active cells".

2.2. The Vector Field Histogram (VFH)

The Vector Field Histogram was developed with the aim to be computationally efficient, robust, and insensitive to misreading. In practice, the VFH algorithm has proven to be fast and reliable, especially when traversing densely populated obstacle courses.

The VFH algorithm contains three major components:

- Cartesian histogram grid: a two-dimensional Cartesian histogram grid is constructed with the robot's range sensors, continuously updated in real time.
- Polar histogram: a one-dimensional polar histogram is constructed by reducing the Cartesian histogram around the momentary location of the robot.
- Candidate valley: consecutive sectors with a polar obstacle density below threshold, known as candidate valleys, are selected based on the proximity to the target direction.

Once the direction of the center of the selected candidate direction is determined, the orientation of the robot is steered to match. The speed of the robot is reduced when approaching the obstacles head-on.

2.3. The Combined Vector Field (CVF) Method

As a first attempt at avoiding obstacles with large, rectangular-shaped mobile robots Borenstein and Raschke [1991] de-veloped the combined vector field (CVF) method, this combines the VFF and VFH method. With this method, the principle steering direction of the non-point robot is determined by the VFH algorithm, since stable motion and better spatial resolution are the strength of the VFH method; while the VFF algorithm applies virtual forces as a corrective measure to account for the robot’s dimension.

2.4. VFH+

The VFH algorithm was improved in 1998 and renamed the VFH+ Enhancements include:

- Threshold hysteresis: a hysteresis increases the smoothness of the planned trajectory.
- Robot body size: robots of different sizes are taken into account, eliminating the need to manually adjust parameters via low-pass filters.
- Obstacle look-ahead: sectors that are blocked by obstacles are masked in VFH+, so that the steer angle is not directed into an obstacle.
- Cost function: a cost function was added to better characterize the performance of the algorithm, and also gives the possibility of switching between behaviors by changing the cost function or its parameters.

2.5. The Double-VFH (DVFH) Method

Hong Yang1, Johann Borenstein1, David Wehe (1999) developed the Double-VFH (DVFH) method, a modification of the original VFH method for the elongated, rectangular-shaped mobile robot. DVFH method easily solves the oscillatory tendency. , the robot is based on two trucks, which are kinematically simple differential-drive vehicles. The DVFH algorithm treats these two trucks identically, that is, either one may lead or follow.

Two basic behaviors need to be defined:
Truck A serves as Leader, Truck B serves as Follower;
Truck B serves as Leader, Truck A serves as Follower;

The motion mode generated by the DVFH method is similar to a Follow-the-Leader approach if no obstacle is encountered. However, there is an important distinction between these two apparently similar modes:

While the Follow-the-Leader mode always results in the rear truck following precisely along the trajectory of the front truck, in the DVFH mode, the two trucks determines their own direction of travel in parallel and independently.

This is done according to the following general approach as shown below

- A separate polar histogram is built around the two center points OA and OB, which are located along the longitudinal axes of the robot (as shown in Figure 1). The optimal location of OA and OB depends on the dimension of the robot and its nominal travelling speed, and these positions should be determined experimentally.
- Using the original VFH method as candidate direction vectors VA and VB are calculated separately for each polar histogram centered at OA and OB.

A Cost-Based Arbitration scheme is applied to resolve conflicts between the separately determined VA and VB in order to find a set of realizable directions, which result in the de-sired trajectory.

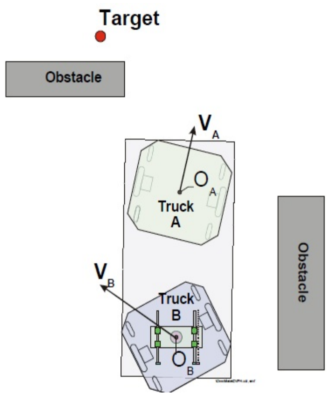


Fig 1: DVFH selects directions for two center points located along the longitudinal axis of the robot.

2.6. VFH*

H* improves upon the original VFH algorithms by explicitly dealing with the shortcomings of a local planning algorithm, in that global optimality is not ensured. In VFH*, the algorithm verifies the steering command produced by using the A* search algorithm to minimize the cost and heuristic functions. While simple in practice, it has been shown in experimental results that this look-ahead verification can successfully deal with problematic situations that the original VFH and VFH+ cannot handle (the resulting trajectory is fast and smooth, with no significant slowdown in presence of obstacles).

3. A* Search Algorithm

Peter Hart, Nils Nilsson and Bertram Raphael first described the **A*** algorithm in 1968 is a computer algorithm that is widely used in path finding and graph traversal, the process of plotting an efficiently traversable path between points, called nodes. It is an extension of Edsger Dijkstra's 1959 algorithm. A* has been generalized into a bidirectional heuristic search algorithm which uses a best-first search and finds a least-cost path from a given initial node to one goal node (out of one or more possible goals).It uses a distance-plus-cost heuristic function (usually denoted $f(x)$) to determine the order in which the search visits nodes in the tree. The distance-plus-cost heuristic is a sum of two functions: 1) the path-cost function, which is the cost from the starting node to the current node (usually denoted $g(x)$) and 2) an admissible and optimal "heuristic estimate" of the distance to the goal (usually denoted $h(x)$).

4. Fuzzy Logic Controller And Decision Making System

The four principal components of the fuzzy decision-making systems are:

- The fuzzification interface: determines input and output variables and maps them into linguistic variables that are to be displayed on a universe of discourse.
- The knowledge base: is a part of expert systems that contains the domain knowledge. Membership functions and control rules are decided by the experts at this point, based on their knowledge of the system.
- The decision-making logic: treats a fuzzy set as a fuzzy proposition. One fuzzy proposition can imply another, and two or more fuzzy proposition can be associated by a Boolean connectivity relation to infer a final fuzzy proposition.
- The defuzzification interface converts the fuzzy output into a crisp (no fuzzy) value.

4.1. Defining The Linguistic Variables For Inputs And Outputs

The Fig 2 represents the division of space in fuzzy subsets. Here the linguistic variables are the same for the input and output range and direction sets. A range has the subsets: Far (F), Medium (M), and Near (N). A direction has the subsets: Large negative (LN), Medium Negative (MN), Zero Negative (ZN), Zero Positive (ZP), Medium Positive (MP), and Large Positive (LP) .

4.2. Defining The Linguistic Variables For Inputs And Outputs

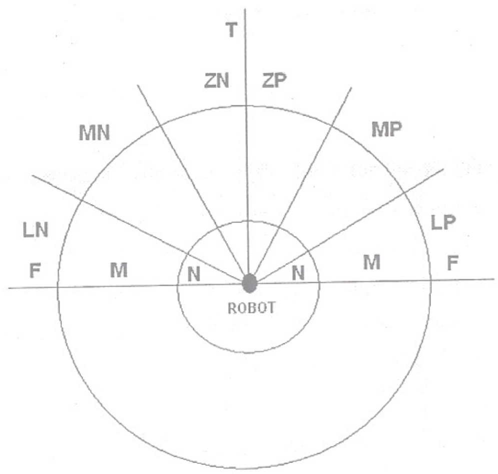


Fig 2: Division of Fuzzy Subsets

- If (range is near and angle is Zero Positive) Then distance is Medium and angle of deviation is Zero Negative
- If (range in near and angle is Zero Negative) Then distance is Medium and angle of deviation is Zero positive.
- If (range is medium and angle is Zero Positive) Then distance is near and angle of deviation is Zero Negative.
- If (range is Medium and angle is Zero Negative) Then distance is near and angle of deviation is Zero Positive.

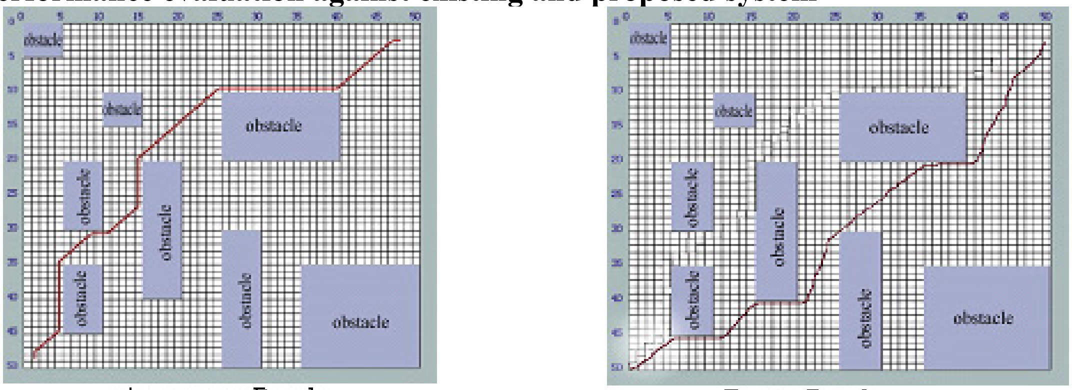
5. Implementation Procedures

The obstacle avoidance system of the autonomous mobile robot comprises a ring of 32 Polaroid ultrasonic sensors, an electronic interface board equipped with four 68HC11 micro-controllers, proximity sensors to detect the obstacles, and software that runs on the robot onboard PC. The development tools used is C Language and Keil software, which is a part of Microsoft turbo C and 89C52 IC. As C is used for the implementation of the project; the operating environment is window. This project can be made to run on any updated system. The minimum configuration is Intel Pentium Processor with the RAM capacity of 256 MB. In order to execute the code, HEX files. The algorithm used for implementation is DVFH *(Double - Vector field histogram) algorithm and A * search algorithm.

6. Experimentation and results

The Fig 3 shows the performance evaluation between the experimental results of existing and proposed system. In the existing system the robot is not able to take the shortest path and sideways grabbing and diagonal motion to reach the target by avoiding the obstacles which is a time consuming process By applying A * optimal path finding algorithm In our proposed system the existing system can be reincarnated to overcome the above said constraint.

6.1. Performance evaluation against existing and proposed system



Appearance Based Feature Based

Figure 3: Sample Navigation Results

7. Conclusion

This project deals with the real-time navigation of a mobile robot in a totally unknown environment. It applies fuzzy reasoning to endow a mobile robot with the human being ability to reason and perceive danger, where just four of them trigger the fuzzy rules. Thus using the algorithms like DVFH, VFH* and A* the robot is able to reach the target in a shortest path which reduces the total transportation cost during the navigation. This proposal has been validated in different unknown environments cluttered with static and dynamic obstacles and has proven to give the robot, a means of safely reaching the target.

8. Acknowledgements

We would like to acknowledge the support of many individuals who have willingly helped us out with their abilities. We are highly indebted to our Principal Dr.S.Ragunathan, M.E., Phd. who encouraged us to pursue this topic .We submit our thanks to our colleague Mr.K.Vinodh Bharadwaj for helping us to achieve a clearer structure.

9. References

[1] Carole Fayad and Dr.Phil Web, Manufacturing Engineering Department, University of Nottingham, U.K. “Optimized Fuzzy Logic Based Algorithm for a Mobile Robot Collision Avoidance in an Unknown Environment”, *IEEE transaction on Mechatronics*, August 2002, vol.3, pp.36-49.

[2] Hong Yang, Johann Borenstein and David Wehe, department of Mechanical Engineering and applied mechanics, Univeristy of M Michigan, USA. “Double – VFH: Reliable Obstacle Avoidance for Large, Non- Point, Omnidirectional Mobile Robots”, *ANS conference on Robotics and Remote systems*, April 1999.

[3] Iwan Ulrich and Johann Borenstein, Advanced technology laboratory, University of Michigan, USA. “VFH+: Reliable Obstacle Avoidance for Fast Mobile Robots”, *IEEE transaction on robotics and automation* May 1998, pp.1572-1577.

[4] Rajibul Huq, Geoge K.I.Mann, and Raymond G.Gosine “Behavior-modulation technique in mobile robotics using fuzzy discrete event system”, *IEEE transaction on Robotics*, October 2006 , Vol.2,pp.43-56.

[5] Timothy j.Ross” *Fuzzy logic with engg appln”,* McGraw Hill 1997.

[6] http://www.csail.mit.edu.

[7] http://www.robots.mit.edu.

[8] http://www.robotics.eecs.berkeley.edu.

[9] http://www.ri.cmu.edu.

[10] http://www.ai.stanford.edu