ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019

Distributed Adaptive Cooperative Hunting Algorithm for Multiple Autonomous Underwater Vehicles

S.Arasi[1], Dr.P.Sivakumar,Ph.D.,[2]

P.G. Student, Department of ECE, GRT Institute of Engineering and Technology, Tiruvallur, Tamil Nadu, India [1]

Professor, Department of ECE, GRT Institute of Engineering and Technology, Tiruvallur, Tamil Nadu, India [2]

ABSTRACT: This paper investigates the attitude consensus problem of multiple Autonomous Underwater Vehicles (AUVs) in the case of communication delay with the directed communication network. A distributed adaptive integral sliding mode controller is designed for each vehicle to track the desired attitude. The inertia uncertainty and external disturbance in the dynamics of AUV are considered in designing the control law. Multi-AUV cooperative hunting is a very challenging research area, a novel multi-AUVs bio-inspired cooperative hunting algorithm is presented. Firstly, a bio-inspired Neural Network model (BINN) is established to represent the AUV underwater working environment. Each point in the grid map corresponds to the activity of a neural activity in the BINN, and the next target point of the hunting AUV can be planned autonomously according to the neuron activity of the neurons in the BINN. Secondly, the direction decision algorithm is embedded into the BINN hunting model for the ocean current environment, and the four hunting AUVs all move from the left side of the map, with the rhombic formation to hunt the evader AUV. And the integrated algorithm proposed is compared with the hunting method without direction decision. Finally, simulation results are presented to demonstrate that the proposed algorithm is effective for cooperative hunting mission.

KEYWORDS: AUV , BINN , A*, Hunting

I. INTRODUCTION

An autonomous underwater vehicle (AUV) is a robot thathas intelligence and can complete tasks in the ocean by itselfwithout the guidance of operator. It has been widely usedin both civilian areas (deep ocean investigation, maintenanceof underwater devices and so on) and military. Since one single AUV has limited capacity, multi-AUV system has become a more and more hot topic. With the cooperation and coordination, the multi-AUVsystem can improve thecapacity of a single AUV. Researchershasfinishedmany studies on multi-AUV system, including underwatercooperative search, mine sweeping formation control, dynamic task assignmentcooperative hunting and so on. These studies onmulti-AUV system are all interesting and worthy of studying,but cooperative hunting is more comprehensive. The comprehensive hunting problem includes three sub tasks: search ofevaders, formation of a dynamic hunting alliance, and pathplanning until successful capture.There have been many researchers completing someremarkable studies on the overall hunting problem.Most studies are about hunting problem of homogneousAUVs. So far, there is almost no research on thehunting problem of inhomogeneous multi-AUV and intelligent evaders. Some researches about task allocation during hunting have been completed, but lacks of research onthe task allocation in the inhomogeneous multi-AUV hunting problem. What is more, many researches do not discuss on the problem that the evaders have some strategyto escape. In military applications, the multi-AUV huntingsystem often needs to capture invaders with certain intelligence such as micro robots, and their intelligencewill help them to escape. In practical, AUVs in the hunting team are often of different type and possess distinctability such as different sailing speed or different safetydistance, and the evader could have certain intelligence toescape too.

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019

II. RELATED WORK

1. Attitude control of a micro AUV through an embedded system -2017

The Dynamic model is described by Newton-Euler equations. It presents vehicle's performance validation with help of MatLab Simulink and experimental results in real time

2. Multi-AUV target search based on bioinspiredneurodynamics model in 3-D underwater environments-2016

The target globally attracts the AUVs through the dynamic neural activity landscape of the model, while the obstacles locally push the AUVs away to avoid collision. Finally, the AUVs plan their search path to the targets autonomously by a steepest gradient descent rule.

3. Mathematical modeling and analysis of multirobot cooperative hunting behaviors-2015

The mathematical model is formulated by a set of rate equations. The evolution of robot collective hunting behaviors represents the transition between different states of robots. The complex collective hunting behavior emerges through local interaction.

III. PROPOSED ALGORITHM

Cooperative hunting of multi-autonomous underwater vehicle (AUV) is an important research topic. Current studies concentrate on AUVs with the same speed abilities and mostly do not consider their speed differences. In fact, AUVs in a hunting group are often of different types and possess different maximum sailing speeds. For inhomogeneous multi-AUV, a novel time competition mechanism is proposed to construct an efficient dynamic hunting alliance. Hunting team with AUVs possessing higher speed abilities is more suitable for the vast underwater environment. In the pursuing stage, AUV needs to act fast enough to avoid the escape of evader.
After forming the hunting alliance, a hybrid path planning approach is proposed in order to begin hunting as soon as Possible. The approach combines GBNN and belief function path planning method. On the one hand, GBNN requires noprior knowledge and no learning procedures. On the otherhand, belief function can affect the path of AUV locally tomake a more reasonable trajectory. In addition, it is suitablefor both static and dynamically varying environment. Thisstudy is different from many researches that the intelligenceof evader is further discussed too, which makes the huntingharder and more complex. The proposed task allocation andpath planning approach is computationally stable in the study. It can cope with the cooperative hunting of multi-AUV forintelligent evaders efficiently as well as improve hunting efficiency.

In the hunting, AUVs should search for evaders first. Afterany evader is found, a dynamic hunting alliance will beformed among AUVs. The AUV, which is not in the dynamicalliance, will search for other evaders. Hunting AUVs inthe team will plan a path to capture the seen evader by thecombined path planning algorithm. After all the evaders are seen and captured, the hunting ends.Hunting alliance formed among inhomogeneous multi-AUV and path planning to round up the evader are two keen problems of this paper. The influence factors such as differentspeed and safety distance of AUVs should be taken intoconsideration in the hunting process. Because the evader willtry their best to escape, there are other problems to be solvedincluding how to avoid run-away of the intelligent evader andobstacle avoidance

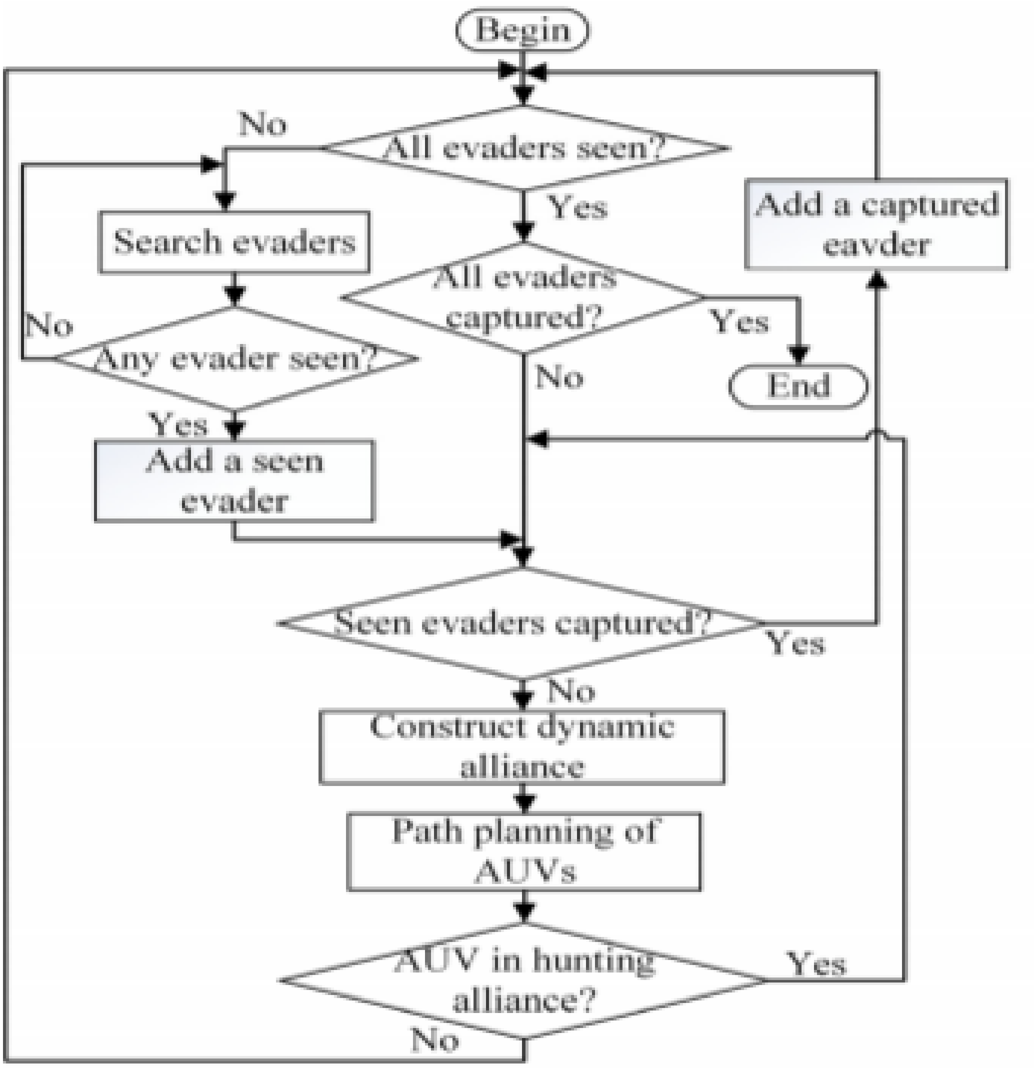
ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019



The neural activity propagation of GBNN model worksa bit like wave propagation in a lake. If wave starts in themiddle of the lake, it takes some time to spread to the shoreside. The broader the lake is, the longer the spread will be.The single GBNN model needs some time to propagate theneural activity at the target's grid to the position of AUV. Thecombined algorithm applies belief function as a local effectand this effect is relatively large when the AUV is far awayfrom its target because of the small GBNN activity value atthat place. It can eliminate the time delay for the propagationof GBNN model. As time goes up and AUV goes near toits target, GBNN will take charge of the AUV. The neuralactivity of GBNN at the obstacle unit is equal to zero, andthat of belief function method is less than zero. However,the neural activity of free unit on the direction to get closerto the target is higher than zero and increases as the distanceto the target decreases. Therefore, even if the target or theobstacle is dynamic, the combined approach will ensure theactivity of the obstacle less than that of the free unit. Thatis to say, the activity propagates from the target to

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

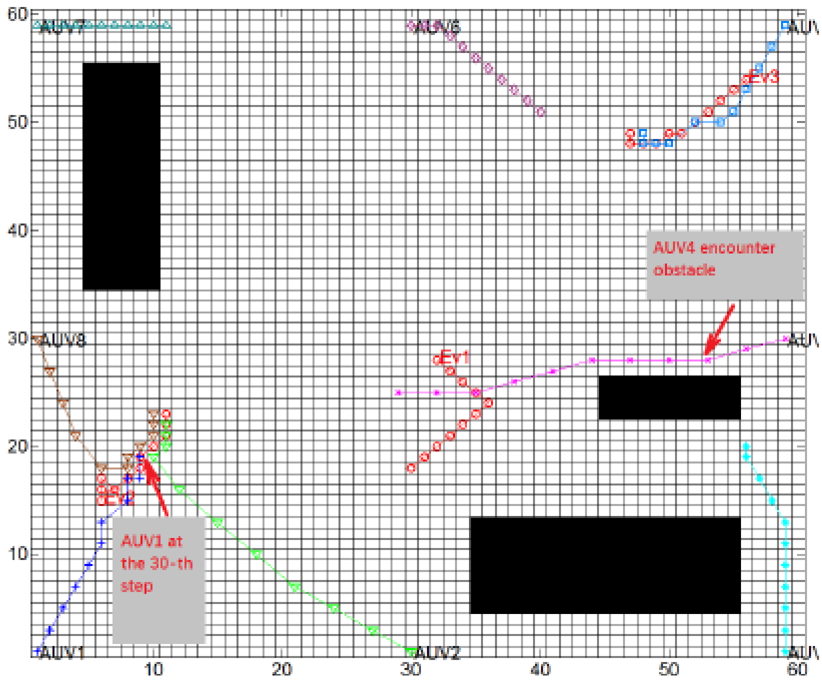
(A High Impact Factor, Monthly, Peer Reviewed Journal)

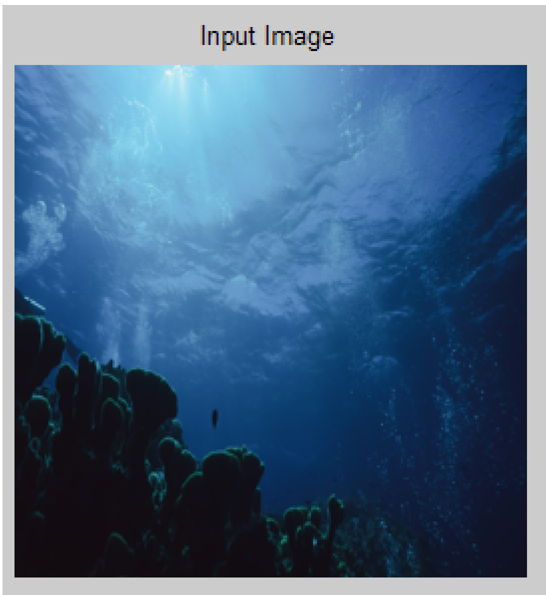
Website: www.ijircce.com

Vol. 7, Issue 3, March 2019

the AUVgradually, and has a relatively small value at the obstacle unit.In conclusion, the AUV, which takes the next step with thebiggest total neural activity, will reach the target with obstacleavoidance.

IV. RESULTS AND DISCUSSIONS





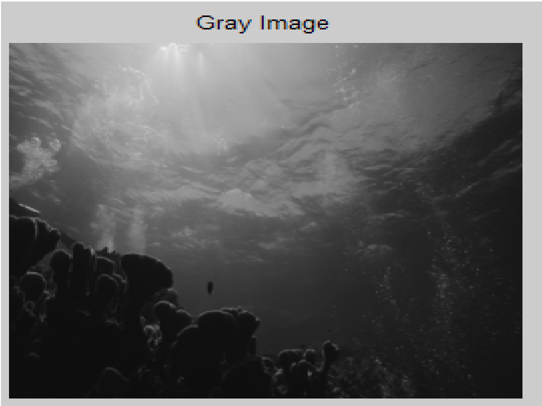
ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

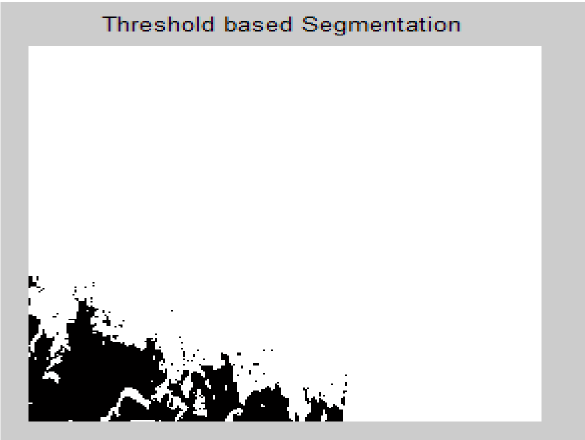
International Journal of Innovative Research in Computer and Communication Engineering

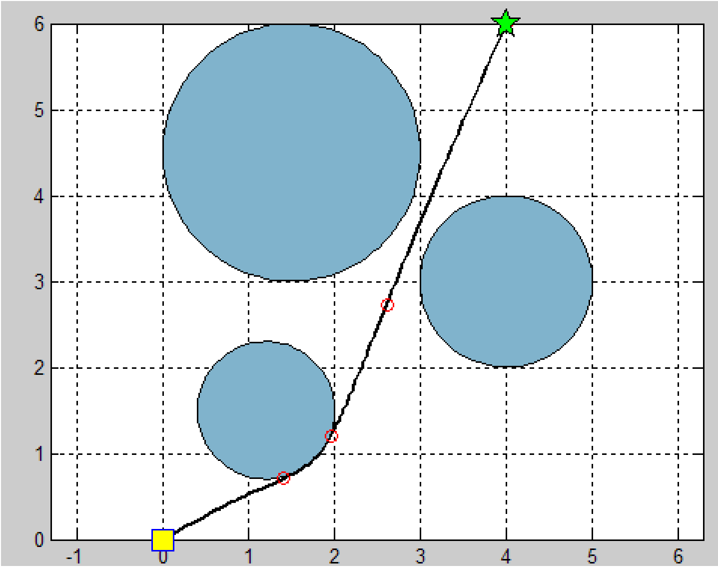
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019







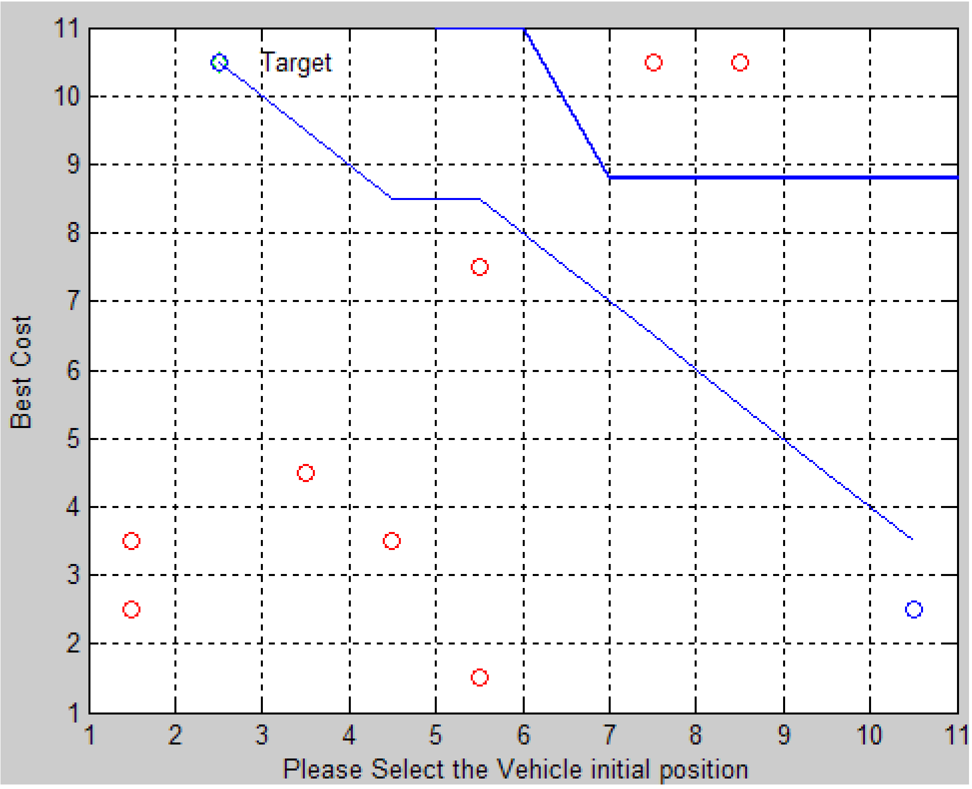
ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019



V. CONCLUSION AND FUTURE WORK

Then GBNNand belief function method are combined for a highly efficient path planning. The feasibility and effectiveness of the proposed algorithm are verified by simulation. The algorithmproposed is compared with original distance competitionalgorithm and single GBNN model. The results show thatthe proposed algorithm is more efficient. The single GBNNmodel works badly in such a fast dynamic environment ashunting, and it takes more distance to nish the hunting task.The distance-based hunting alliance algorithm is not good atthe hunting alliance formation of inhomogeneous AUVs too.The proposed algorithm can reduce the hunting steps withless AUVs' total distance and evaders' escaping distance.At last, it is demonstrated that the algorithm can also fulll thehunting in the 3-D underwater environment where the evadercan run away more easily.

REFERENCES

[1] M. Sibenac, T. Podder, W. Kirkwood, and H. Thomas, ``Autonomousunderwater vehicles for ocean research: Current needs and state of theart technologies," Marine Technol. Soc. J., vol. 38, no. 2, pp. 6372,2004.
[2] M. L. Corradini and G. Orlando, ``A discrete adaptive variable-structurecontroller for MIMO systems, and its application to an underwater ROV,"IEEE Trans. Control Syst. Technol., vol. 5, no. 3, pp. 349359, May 1997.
[3] D. R. Blidberg, ``The development of autonomous underwater vehicles(AUV); A brief summary," IEEE ICRA, vol. 17, no. 5, pp. 209212, 2008.
[4] J. A. Monroy, E. Campos, and J. A. Torres, ``Attitude control of a microAUV through an embedded system," IEEE Latin Amer. Trans., vol. 15,no. 4, pp. 603612, Apr. 2017.
[5] T.-H. Joung et al., ``A study on the design and manufacturing of a deep sea unmanned underwater vehicle based on structural reliability analysis,"Ships Offshore Struct., vol. 4, no. 1, pp. 1929, 2009.
[6] A. Farinelli, L. Iocchi, and D. Nardi, ``Multirobot systems: A classicationfocused on coordination," IEEE Trans. Syst., Man, Cybern. B, Cybern.,vol. 34, no. 5, pp. 20152028, Oct. 2004.
[7] W. Xing, Y. Zhao, and H. Karimi, ``Convergence analysis on multi-AUVsystems with leader-follower architecture," IEEE Access, vol. 5,pp. 853868, 2017.

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 7, Issue 3, March 2019

[8] Q. W. Liang and T. S. L. Shi, ``Reliability analysis for mutative topologystructure multi-AUV cooperative system based on interactive Markovchains model," Robotica, vol. 35, no. 8, pp. 17611772, 2016.
[9] S. Yoon and C. Qiao, ``Cooperative search and survey using autonomousunderwater vehicles (AUVs)," IEEE Trans. Parallel Distrib. Syst., vol. 22,no. 3, pp. 364379, Mar. 2011.
[10] X. Cao, D. Zhu, and S. X. Yang, ``Multi-AUV target search basedonbioinspiredneurodynamics model in 3-D underwater environments,"IEEE Trans. Neural Netw. Learn. Syst., vol. 27, no. 11, pp. 23642374,Nov. 2016.
[11] A. J. Healey and J. Kim, ``Control and random searching with multiplerobots," in Proc. 39th IEEE Conf. Decision Control, Sydney, NSW, Australia, Dec. 2000, pp. 340345
[12] B. Garau, M. Bonet, A. Alvarez, and S. Ruiz, ``Path planning forautonomous underwater vehicles in realistic oceanic current elds: Appli-cation to gliders in the Western Mediterranean Sea," J. Maritime Res.,vol. 6, no. 2, pp. 522, 2009.
[13] A. J. Healey, ``Application of formation control for multi-vehicle roboticminesweeping," in Proc. IEEE CDC, Orlando, FL, USA, Dec. 2001,pp. 14971502.
[14] D. Zhu, H. Huang, and S. X. Yang, ``Dynamic task assignment and pathplanning of multi-AUV system based on an improved self-organizingmap and velocity synthesis method in three-dimensional underwaterworkspace," IEEE Trans. Cybern., vol. 43, no. 2, pp. 504514, Apr. 2013.
[15] J. G. Bellingham, ``New oceanographic uses of autonomous underwatervehicles," Marine Technol. Soc. J., vol. 31, no. 3, p. 34, 1997.
[16] J. Li, Q. S. Pan, B. R. Hong, and M. H. Li, ``Multi-robot cooperative pursuitbased on association rule data mining," in Proc. Int. Conf. Fuzzy Syst.Knowl. Discovery, Tianjin, China, vol. 7. Aug. 2009, pp. 303308.
[17] H. Jun and Q. Zhu, ``A multi-robot hunting algorithm based on dynamicprediction for trajectory of the moving target and hunting points," ActaElectron. Sinica, vol. 39, no. 11, pp. 24802485, 2011.
[18] M. Wu, F. Huang, L. Wang, and J. Sun, ``A distributed multi-robot coop-erative hunting algorithm based on limit-cycle," in Proc. Int. Asia Conf.Informat. Control, Autom.Robot., Feb. 2009, pp. 156160.
[19] R. E. Korf, ``A simple solution to pursuit games," in Proc. 11th Int.WorkshopDistrib. Artif.Intell., 1992, pp. 183194.
[20] J. Li, Q. Pan, and A. B. Hong, ``A new approach of multi-robot cooperativepursuit based on association rule data mining," Int. J. Adv. Robotic Syst.,vol. 6, no. 4, pp. 11691174, 2010.
[21] J. Denzinger and M. Fuchs, ``Experiments in learning prototypical situa-tions for variants of the pursuit game," in Proc. Tech. Univ. Kaiserslautern,FachbereichInf. (ICMAS), Jun. 1996, pp. 4855