Proceedings of the Fourth International Conference on Machine Learning and Cybernetics, Guangzhou, 18-21 August 2005

ROBOT AUTONOMOUS PERCEPTION MODEL FOR INTERNET-BASED INTELLIGENT ROBOTIC SYSTEM

ZHEN-DONG GAO, JIAN-BO SU, WEI ZHOU

Department of Automation & Research Center of Intelligent Robotics, Shanghai Jiaotong University, Shanghai, 200030
E-MAIL: imgordon@sjtu.edu.cn, jbsu@sjtu.edu.cn, zhwme@sjtu.edu.cn

Abstract:

The Internet-based robot is a popular topic in robot control research recently. A platform build to provide information for robot can increase its intelligence and performance of teleoperation greatly. This paper implements the robot system based on the Robot Autonomous Perception Model (RAPM) can get the information on the Internet through autonomous perception, optimize paths based on Genetic Algorithms, and fulfill the mission out of the robot's field range. The experiment shows RAPM possesses greatly extended capability and proper structural frame, and the optimizing way based on GA is effective. This has significant purpose for increasing Internet-based robots intelligence and behavior capacity.

Keywords:

Internet-based robot; Genetic Algorithms; information perception; RAPM

1. Introduction

The Internet-based robot is a popular topic in robot control research recently [1, 2]. In 1994 Ken Goldberg and colleagues proposed the concept of "Internet-based robot". They built a system that allows a robot manipulator to be teleoperated via the World Wide Web. Although the field of teleoperation dates back over 50 years, the WWW provides a low-cost and widely-available interface that can make teleoperated resources accessible to a broad range of users.

In recent years to emphasize the intelligence of the robot, the study object of the Internet-based robot replace with mobile robot gradually [11, 12]. Because of the limitation of data-handling capacity, the mobile robot cannot process excess data, decision and controlling. It is very difficult that a robot uses only own sensors to fulfill complex work. So we must build a platform providing the information for the mobile robot. This platform has some capability, such as picking, filtering, identifying, learning and fusing. And the mobile robot achieves corresponding information from the Internet according to the robot's processing capacity to learn, fuse, and control.

Joo-Ho Lee and Hideki Hashimoto proposed the concept of "Intelligent Space". Intelligent Space is a navigation platform for human and robots. In the platform Distributed Intelligent Networked Devices (DIND) can detect the position of the human or robot by theirs color bars, transform into coordinate data, and feedback to the human or robots. The human or robots get own position information and determines the next behavior [4]. There are many solutions for such static network environments [5]. They build on the static network environments and structured spatial object, but the actual network is not static and not structured. There are many problems in Internet, such as random delay, bandwidth limited, data lost, thousands of administrators. At the same time, the actual systems have some failures not in the laboratory systems, for example route failures, services break off, electricity failure. Thus we must build a novel network platform treating with the uncertainty of the dynamic network environments.

In order to meet the uncertainty of the dynamic network, we must adopt a new method to monitor real-timely the information of the dynamic network, and then issue the information to the network user. The key point is to offer a kind of specific information service that establishes an information channel between the service and the network users, thus accomplish communication, interactive operation, controlling between robots and sensors and actuator. In the platform each component of the system interconnected according to the demand, and have spontaneous and plug-and-play connection mechanism.

The paper proposes the Robot Autonomous Perception Model (RAPM) of the Internet-based robot control system and achieved searching for the resource in the system, optimizing paths based on Genetic Algorithms, localizing the mobile robot. In Section 2, RAPM was proposed. And optimizing paths based on Genetic Algorithms is in Section 3. Section 4 is the experimentation. The last Section is a conclusion and the future work.

2. Robot Autonomous Perception Model (RAPM)

Evolved from teleoperation, the researches on the internet-based robot are inspired by the worldwide coverage and convenient communication brought by Internet. Hence the Internet was regard as a channel of command and feedback between robot and teleoperator. Nevertheless, affected by many unpredictable factors, the Internet is not a sufficiently reliable connection. The limited bandwidth and random delay of Internet lead to problems in robot systems.

To avoid above-mentioned problems more and more scholars study on the distributed structure. The distributed structure robot control system can solve effectively those problems. In the structure, the teleoperator, the robot and the outside sensors (video servers) dispersing on different nodes of the Internet network compose a distributed structure robot system, as shown in Fig.1. Joo-Ho Lee and Hideki Hashimoto build a distributed intelligent sensor network based on Linux and C++ [4]. Hori encapsulates the control of arm and build a robot control platform [9]. And Hori proposes the robot control method based on the distributed object. These studies work on static network. While the information, robots and the users of the network are not static and not structured. So perceiving resource is the absolutely essential ability of the Internet-based robot.

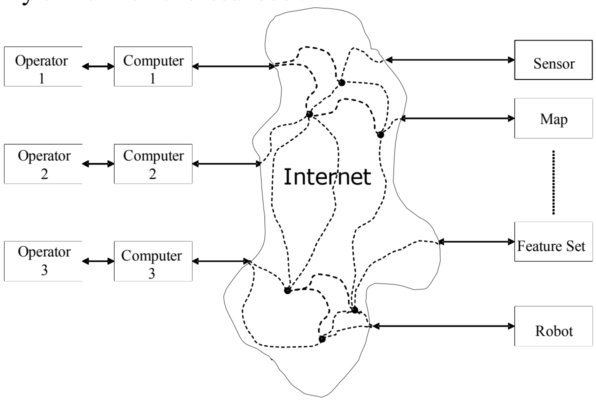


Figure.1 Distributed structure

To abstract the Internet-based robot entities, this paper proposes the Robot Autonomous Perception Model (RAPM). RAPM affords the ability to the Internet-based robot that can autonomous dynamically find and utilize the resource on the Internet. RAPM based on Jini. Jini is a middleware to build a distributed system through Java [10]. Socket and RMI (Remote Method Invocation) is the basic mechanism of the Jini. Jini can implement the plug-and-play soft bus. If a new device or a service joins the network, the clients can get and use it. So the Internet-based robot adopting RAPM not only has more advantages on multi-robot cooperation, but also has dynamic expansion ability greatly through countless sensors connecting to the robot system. In a sense, the more perception the robot obtains, the higher the intellectual level that the robot has. So the distributed information mode and perceive ability greatly improve intellectual level and teleoperation performance of the robot.

There are five basic concepts of the Robot Autonomous Perception Model (RAPM):

Lookup Service: It is a basic service of the RAPM. Any service must be found and confirmed by Lookup Service. And the connection between the system and the users also realize through Lookup Service. Lookup Service is equivalent to the billboard of the network service. It makes the attribute interface of the service corresponding with the object sets of the realization. The object of the service may include the other Lookup Service, thus shape the hierarchical structure. Lookup Service is applied to lookup resource and invoked the service. And its Interface type (compiled by Java) or attributes described services, as shown in Fig. 2 (a).

Discovery: Before a RAPM entity (a video server or an Internet-based robot) uses other services, it must find one or a lot of RAPM colonies, via looking for the Lookup Service with the shared resource in this colony. The course that looks for the valid Lookup Service is called Discovery. For Lookup Service, one colony may many-to-many map, viz. every Lookup Service can offer service to more than one colony and every colony can have more than one Lookup Service server.

Lookup: It is a course of obtaining the Lookup Service function. In every RAPM colony, the Lookup is equal to catalogue service and offers service that looking for known services in a colony.

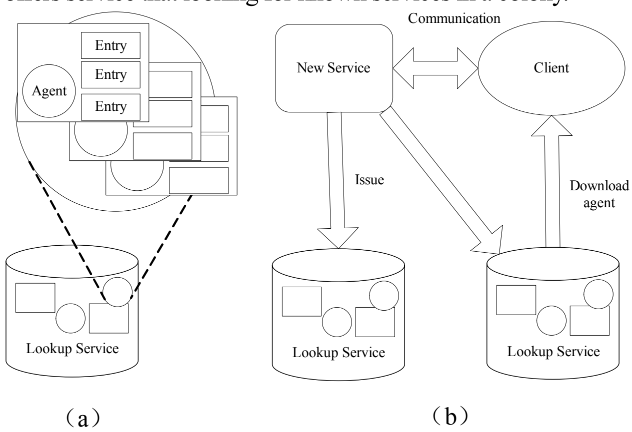


Figure.2 RAPM

Issue: When some equipment or the application programs join the network, its service find the network and admitted by the network at first. This course is called Issue. Before equipment or an application is Issued, they need pass Discovery protocol and Register protocol. The equipment or application transfer Service Entry as parameter to Lookup Service, such as service name, service position, and commentary.

Invoke: The client gets the Service Entry of the service that Issued through Lookup Service, and downloads service object from the server. So the client can communicate with the service through the agent, namely Invoke, as shown in Fig. 2 (b).

Now describe how the RAPM is applied to implement the spontaneous and plug-and-play connection mechanism in the distributed Internet-based robot system. As Fig. 3 shows, take video sensor as an example: First of all, the remote object packing sensor service joins the Jini network and locates Jini Reggie server (1); and get the stub from Jini Reggie server, called Registrar Object (2); through the Registrar Object, the sensor object issue into the Reggie server (3); the remote object packing the robot system joins the Jini network and locates Jini Reggie server (4); download the Registrar Object (5); then the remote object Lookup the corresponding sensor service through the Registrar Object (6); and download the service (7); at last, the robot object locates the corresponding sensor object through the service object (8), build the network link (9). This is the process that implements the spontaneous and plug-and-play connection mechanism between the units of the robot system.

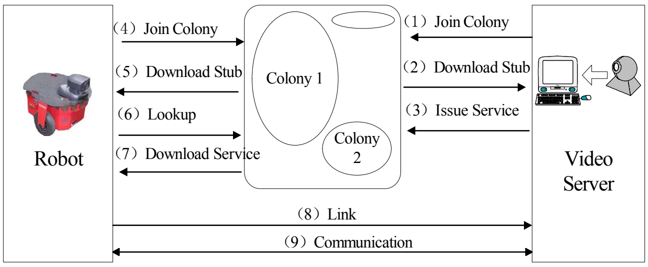
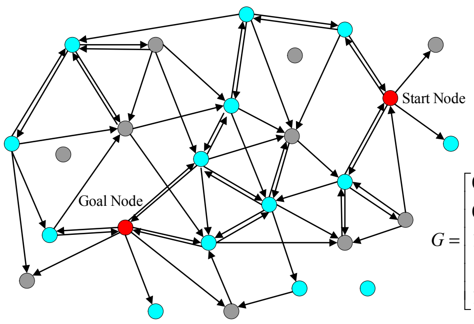


Figure.3 Build service

3. Optimizing Paths Based on GA

A dynamic network can transfer into a temporary static network through the RAPM. In the temporary static network, each video server offers own service information to the Lookup Services of more or less colonies. The mobile robot can get the information of the sensor resource from the Lookup Services through the RAPM. Usually the information has classified according to the attribute. So the same type nodes compose a directed graph, as shown in Fig. 4.



$$G=\begin{bmatrix}0 & 1 & 0 & \cdots & 1\\ 0 & 0 & 0 & \cdots & 1\\ 1 & 1 & 0 & \cdots & 1\\ \vdots & \vdots & \vdots & \ddots & \vdots\\ 1 & 0 & 1 & \cdots & 0\end{bmatrix}$$

Figure.4 directed graph and adjacency matrix G

In the Fig. 4, the red points indicate the video server nodes, which find the goal or the robot; the blue points indicate the video server nodes, which are available; the gray points indicate the video server nodes, which are unavailable. And the directed lines denote there is overlapping area between the video server nodes.

For one robot, it is a path planning problem to get the path from the start node (the video server node that the mobile robot is in) to the goal node (the video server node that the goal is in). there are many solutions for the problem, such as, Breadth-First Search (BFS), Depth-First Search (DFS), A*, RBFS, and some learning algorithms. While for multiple robot paths, the paths maybe have crossing over. In the paper it expresses several robots use the same nodes (video servers) at the same time. Therefore must optimize the route of the mobile robots so that robots use the same nodes at different time or use the different nodes. Genetic Algorithms is an effective method on optimizing [8]. So this paper adopts GA to solute the path planning problem.

First of all, apply the adjacency matrix G to denote directed graph. It is a $N\times N$ matrix. Assume there is K nodes that are available, and include the video server nodes that find the goal or the robot and the other available video server nodes. Then $N=K$. The nodes express as $M_0, M_1, M_2, \cdots, M_{k-1}, M_k$, where i row in the matrix remark the M_i in the directed graph. If there is a line from M_i to M_j in the directed graph, G_{ij} is marked 1, or else 0.

Coding: To signify the path distinctly, here adopt Symbolic Coding, such as:

$$D=\{G_{2,1}, G_{2,3}, G_{11,6}, \cdots, G_{8,11}\} \quad (1)$$

Fitness Function: To avoid robots using the same nodes at the same time, the Fitness Function include three parts. The one is the sum of all nodes that the robots will pass through. The two is the sum of the nodes that the robots will pass through at the same time. The three is the influence between robots.

$$\min F_{short}=(D_1+D_2+,\cdots,+D_m)+\eta\rho_1(D_1,D_2,\cdots,D_m) +\xi\left(\frac{1}{\rho_2(D_1,D_2)}+\frac{1}{\rho_2(D_1,D_3)}+,\cdots,\frac{1}{\rho_2(D_{m-1},D_m)}\right) \quad (2)$$

where

$D_1, D_2, \cdots, D_m$ is the paths of robot,

$\rho_1(D_1, D_2, \cdots, D_m)$ is the sum of use the same nodes at the same time between $D_1, D_2, \cdots, D_m$,

$\rho_2(D_1, D_2, \cdots, D_m)$ is the sum of influence between every two robots that use the same nodes at the not same time,

η, ξ are the constant coefficient of ρ_1 and ρ_2 separately. Here $\eta=\xi=1$.

Initial Population: To restrain premature convergence, choose a part as the initial population at random by BFS and DFS.

Selection Operator: Select some individuals that direct ratio with the Fitness Function to the offspring population.

Crossover Operator: Crossover two parts which are between two same nodes in two individuals.

Mutation Operator: Replaced one node that has been used by other robot with new node near the old one. If the new path is discontinuous, the Mutation is invalid.

Delete Operator: Delete the nodes between the same nodes of one path to simplify the path.

Parameters are shown in Table 1. The Procedure flowchart is shown in Fig. 5.

Table 1 Function and Parameters of GA

Function name	Parameters
Node number	30
Robot number	3
Population size	36
Step number	100
Two-point crossover (%)	0.8
Mutation (%)	0.01

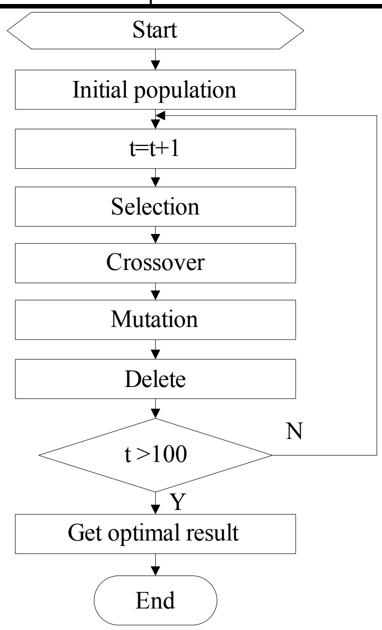


Figure.5 Procedure flowchart

Table 2 Statistic results

No.	Before optimizing	Expectance value	After optimizing	Optimum ratio
1	14.7	12	12.2	83%
2	18.1	15	15.3	75%
3	19.5	16	16.3	76%
4	21.0	17	17.7	67%
5	23.9	18	18.6	69%
6	26.8	20	21.2	52%

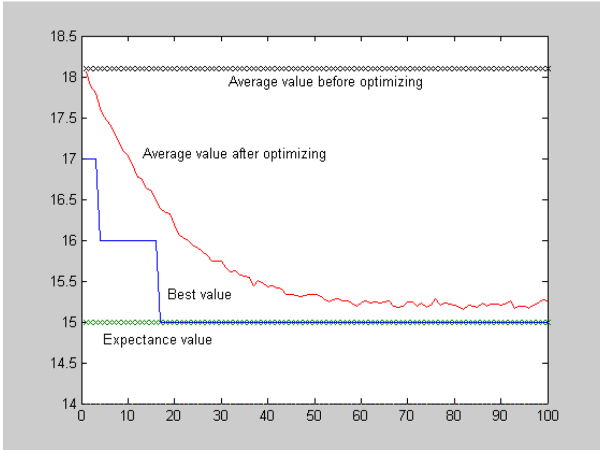


Figure.6 Optimizing based on GA

Statistic results are shown in Table 2. Because the initial population is chosen through BFS and DFS, the simulation results are better than those of BFS and DFS. And another conclusion from the Table 2 is that it easily gets the optimal path when the distance is short between start point and end point. Fig.6 is the 2nd experimentation result.

4. Experiment

The experimental platform adopts Pioneer2DX mobile robot of ActiveMedia Company as the experimental object. The robot has two level DOF and one rotating DOF. And install Sony EVID31 camera that has three degree of freedom (Pan-Tilt-Zoom) as the robot head and vision sensor. There are an odometer and 8×2 sonar sensors inside the robot. Meanwhile, there are several network cameras as vision sensor. The vision sensors access the network or Internet through computers. These vision sensors and computers compose the video severs.

On the software, for increasing the expansion greatly, the system adopts Object-oriented Programming (OOP) first of all. The whole of system realizes the interface and encapsulates object based on Java, and applies RMI to build remote object interface, and utilities Jini to implement the spontaneous and plug-and-play connection mechanism.

The following is the whole experiment course. Experiment is two robots search a blue goal and a yellow goal at a distance. Robots cannot found the goals though own sensors. First of all, start the Jini server. The 2nd step is two robots and video servers join the Jini network and register information into the Jini server. The 3rd step Robots get the information of the goals, and the video servers. The 4th step is optimizing paths based on GA. The 5th step, two robots move to the goal. The path of robot 1 is A-E-F, and the path of robot 2 is B-C-E. Finally every robot enters the video server where the goal is. Because the robots have closed the goal, they use own vision sensor through rotating to search, approaches the goal and finish the mission. Experiment is shown in Fig.7.

The experiments show RAPM possesses greatly extended capability and proper structural frame, and the optimizing way based on GA is effective.

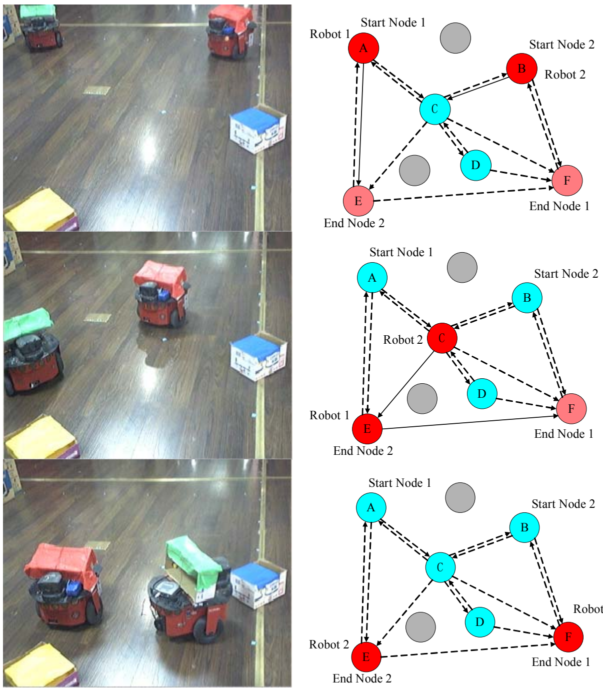


Figure.7 Robot real movement path

5. Conclusion and Future Work

This paper proposes the Robot Autonomous Perception Model (RAPM). The Internet-based robot can perceive and utilize the information resource, such as video server, through the Internet. This is a novel approach for the Internet-based robot control system. Optimizing the robot paths based on GA can get the better results. Experiment indicates the mobile robots utilizing the uncertain information resource and planning paths based on GA can improve its intelligent and capacity greatly, and fulfill quickly complicated mission through the cooperation between the mobile robots and several network sensors.

Because of RAPM has great expansion, some other devices and algorithms can join the system through the Jini protocol, and offer theirs services. So the future work is inducting more devices and algorithms into the system to provide more the information resource to the robot and improve its intelligent and capacity.

Acknowledgements

This work was financially supported by the National High-Tech R&D Program of China under grant 2001AA422260.

References

[1] Thomas B. Sheridan, "Space Teleoperation Through Time Delay, Review and Prognosis," IEEE Transactionon Robotics and Automation, Vol.9, No. 5, pp. 592-606, 1993.

[2] Anderson R J, Spong M W. Bilateral, "Control of Teleoperators with Time Delay," IEEE Transactions on Automation Control, Vol. 34,No. 4, pp. 494-501, 1989.

[3] D. E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning," Addison Wesley, 1989.

[4] Joo-Ho Lee, and Hideki Hashimoto, "Controlling Mobile Robots in Distributed Intelligent Sensor Network," IEEE Transactions on Industrial Electronics, Vol. 50, No. 5, pp. 890 - 902, October 2003.

[5] Maxim A. Batalin, Gaurav S. Sukhatme, "Using a sensor network for distributed multi-robot task allocateion," Proceedings of IEEE Inter. Conf. On Robotics and Automation, New Orleans, USA, pp. 158-164, April 2004.

[6] Xueqiao Hou, Jianbo SU, "New Approaches to Internet Based Intelligent Robotic System", Proceedings of IEEE Inter. Conf. On Robotics and Automation, New Orleans, USA, pp. 3363-3368, April 2004.

[7] Davis Led, "Handbook of Genetic Algorithms," New York, Van No strand Reinhold, 1991.

[8] Cem Hocaoglu, Arthur C. Sanderson, "Planning Multiple Paths with Evolutionary Speciation," IEEE Transactions on Evolutionary Computation, Vol. 5, No.3, pp. 169-191, June 2001.

[9] T. Hori, H. Hirukawa, T. Suehiro. "Networked robots as distributed objects", Proceedings of the International Conference on Advanced Intelligent Mechatronics, Atlanta, USA, pp.61-66, 1999.

[10] W. Keith Edwards, "Core Jini," Indiana: Prentice Hall PTR, 2000.

[11] Maeyama, Shoichi et al, "Remote museum system using a networked robot," Advanced Robotics, Vol. 13, No. 3, pp. 227--360, 1999.

[12] Reid Simmons, Joaquin L. Fernandez, Richard Goodwin, Sven Koenig, and Joseph O'Sullivan, " Lessons Learned from Xavier," In IEEE Robotics & Automation Magazine, pp. 33-39, June 2000.