Obstacle Avoidance Algorithm for a Network-based Autonomous Mobile Robot

Sookyung Sohn, Hongryeol Kim, Daewon Kim*, Hongseok Kim, and Hogil Lee**

* Department of Information Control Engineering, Myongji University, Kyungki-Do, Korea
(Tel : +82-31-330-6755; E-mail: sukaa@mju.ac.kr, hr.kim@carrier.co.kr, dwkim@mju.ac.kr)
**Mechatronics Team, Korea Institute of Industrial Technology, Chungchungnam-Do, Korea
(Tel : +81-41-589-8484; E-mail: hskim@chaos.kitech.re.kr, hglee@kitech.re.kr)

Abstract: In this paper, an obstacle avoidance algorithm is proposed for a network-based robot considering network delay by distribution. The proposed algorithm is based on the VFH(Vector Field Histogram) algorithm, and for the network-based robot system, in which it is assumed robot localization information is transmitted through network communication. In this paper, target vector for the VFH algorithm is estimated through the robot localization information and the measurement of its delay by distribution. The delay measurement is performed by time-stamp method. To synchronize all local clocks of the nodes distributed on the network, a global clock synchronization method is adopted. With the delay measurement, the robot localization estimation is performed by calculating the kinematics of the robot. The validation of the proposed algorithm is performed through the performance comparison of the obstacle avoidance between the proposed algorithm and the existing VFH algorithm on the network-based autonomous mobile robot.

Keywords: network, delay, VFH, localization, kinematics

1. INTRODUCTION

Various studies have been performed on network-based systems, since they enable conjunction of various heterogeneous systems and they also minimize the cost for the conjunction simultaneously. These studies are extending to such complex systems as autonomous mobile robots[1][2].

With the autonomous mobile robots, there have been various studies on obstacle avoidance, since the obstacle avoidance is one of the most important features needed for them. Anyway, the obstacle avoidance algorithms have been designed for operation in a single system. Since any delay invoked during the operation is negligible in the single system, the studies have not considered any delay invocation during gathering sensory information.

Studies on the consideration for the delay have been performed in the filed of multiple robot controls, especially for sensory fusion from multiple robots that are distributed physically[3][4].

In this paper, an obstacle avoidance algorithm adequate for a network-based autonomous mobile robot is proposed. The proposed obstacle avoidance algorithm is based on the VFH(Vector Histogram Algorithm)[5] algorithm, and for the network-based robot system, in which it is assumed robot localization information is transmitted through network communication.

In this paper, target vector for the VFH method is estimated through the robot localization information and the measurement of its delay by distribution. The measurement is performed by time-stamp method. To synchronize all local clocks of the nodes distributed on the network, global clock synchronization method is adopted. With the delay measurement, the robot localization estimation is performed by calculating the kinematics of the robot.

The validation of the proposed algorithm is performed through the performance comparison of the obstacle avoidance between the proposed algorithm and the existing VFH algorithm on the network-based autonomous mobile robot.

In the following chapters, the network-based autonomous mobile robot system is introduced in chapter 2. In chapter 3, the location estimation method considering delay by the distribution is proposed for the compensation of the VFH algorithm in the network system. Test conditions and test results under the test conditions for the validation of proposed algorithm are described in chapter 4. Finally, conclusions are described in chapter 5.

2. NETWORK-BASED AUTONOMOUS MOBILE ROBOT

A picture of the network-based autonomous mobile robot is shown in Fig. 1. The robot is an assembly composed of brain module, sensor module and mobile module. The functional modules are interconnected through Ethernet.

The sensor module has 133-channel laser finder with forward 180° range, and 16-channel ultrasonic sensor with 360° range. The sensor module generates sensory information of environmental obstacles by the multiple channel sensors. The mobile module has omni-directional driver controls and three wheel dynamics. Odometry information is generated from the mobile module by encoder reading. The brain module is dedicated to massive calculations for the robot.

All the functional modules for the robot have Linux for their software operating systems. For platform transparency among the heterogeneous modules, dedicated VMs(Virtual Machines) are loaded for the modules.

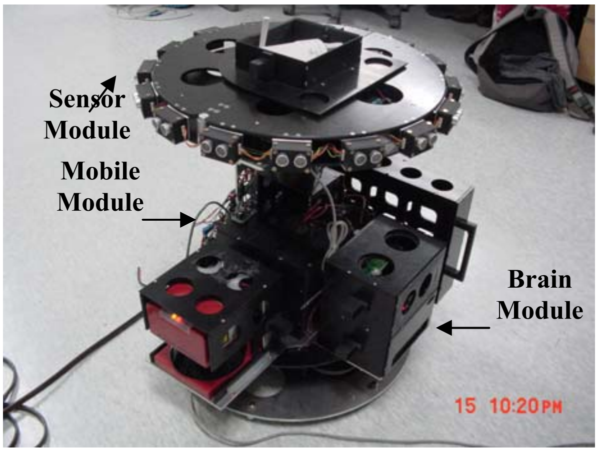


Fig. 1 Network-based Autonomous Mobile Robot

3. OBSTACLE AVOIDANCE ALGIRITHM CONSIDERING DELAY BY DISTRIBUTION

In this paper, the VFH algorithm[5] is used for the basis of the obstacle avoidance for the network-based autonomous mobile robot. The VFH algorithm is known to be adequate for robots in unknown environmental. For the VFH algorithm, sensory information of environmental obstacles and target vector from place where the robot is located to place where target is posed. To calculate the target vector, robot localization estimation is needed. In this paper, the robot localization estimation is performed through odometry information.

In the network-based autonomous mobile robot, the sensory information of environmental obstacles is from the sensor module, and the odometry information is from the mobile module. In this paper the VFH algorithm is operated on the sensor module, and the VFH algorithm receives odometry information through the network communication. Since the odometry information is transmitted through the network, the received odometry information is previous reading value gathered before delayed time by the distribution.

In this paper, current localization estimation from previous odometry information is proposed for the compensation of the VFH algorithm in the networked robot. The localization estimation is performed based on the kinematics of the robot.

Estimated movement of the robot during the delayed time by the distribution is shown in Fig. 2. Where, X_t and Y_t denote the location of the robot when the odometry information request is invoked by the VFH algorithm at the time *t*, $X_t{}'$ and $Y_t{}'$ denote the location of the robot when the odometry information is received by the sensor module at the time *t'*.

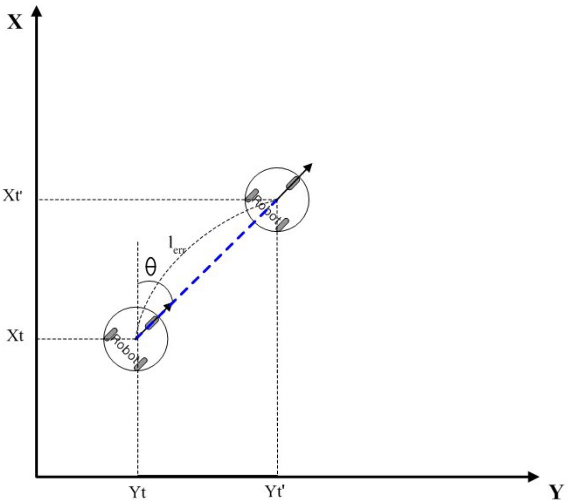


Fig. 2 Robot Movement During Delay by Distribution

In Fig. 2, the delay by the distribution is represented with equation (1), the estimated movement during the network delay is represented with equation (2).

$$D = t' - t \quad (1)$$

$$l_{err} = v \times D \quad (2)$$

Where, D denotes the delay by the distribution, l_{err} denotes the distance of the robot movement during the network delay, and v denotes movement velocity of the robot.

Considering the movement represented with equation (2), the location of the robot when the odometry information is received by the sensor module at the time *t'* is estimated with equation (3).

$$X_t{}' = X_t + \cos\theta \times l_{err}$$
$$Y_t{}' = Y_t + \sin\theta \times l_{err} \quad (3)$$

4. SIMULATION TESTS

4.1 Test conditions

System composition for simulation tests is shown in Fig. 3. As stated above, the VFH algorithm is loaded on the sensor module, and the odometry information is generated at the mobile module.

All tasks on the modules are run on the VMs. Since the operating systems for the operations of the VMs are Linux, the scheduling strategy for the VMs is the round robin method. The time slice of the round robin scheduling for the simulation tests is 200mS.

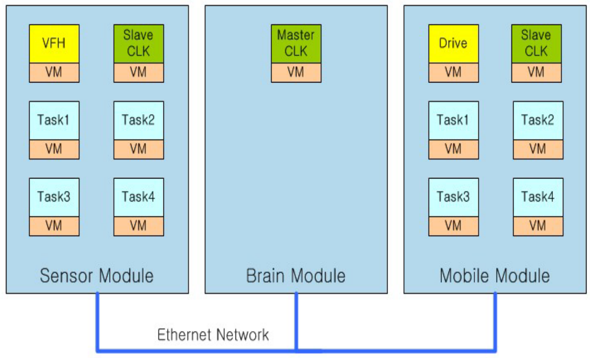


Fig. 3 System Composition for Simulation Tests

To synchronize local clocks at the modules, master clock task(Master CLK) at the brain module transmits global clock periodically to all slave clock task(Slave CLK) located at the modules.

To simulate network load, dummy tasks on the mobile module(Task1, Task2, Task3, and Task4) transmit dummy network messages to the sensor module periodically. The time properties of the network messages are defined as Table 1.

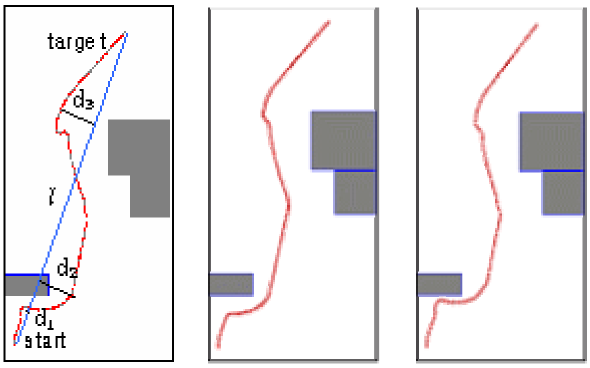
Table 1. Time properties of network messages

Message	Transmission Period	Size
Odometry Information	10mS	22 Byte
Global Clock	500mS	14 Byte
Dummy Message1	100mS	16 Byte
Dummy Message2	120mS	16 Byte
DummyMessage3	140mS	16 Byte
Dummy Message4	160mS	16 Byte

4.2 Test results

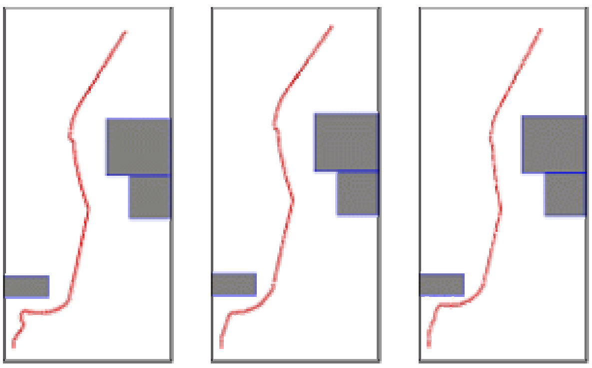
To validate the proposed obstacle avoidance algorithm considering the delay by the distribution, the path of robot movement with the proposed obstacle voidance algorithm and the path of robot movement with the classical VFH algorithm are shown in Fig. 4 and Fig. 5.

As shown in the figures, the robot movement with the proposed algorithm is smoother compared to the robot movement with the classical VFH algorithm. Especially, when the velocity is lower, the difference is bigger. The smoothness in the movement means shorter time consumption and lower energy consumption for the movement from the start position to the target position.



(1)40mm/S (2)50mm/S (3) 60mm/S

Fig. 4 The path of robot movement with the classical VFH Algorithm



(1)40mm/S (2)50mm/S (3) 60mm/S

Fig. 5 The path of robot movement with the proposed algorithm

To quantumize the performance efficiency of the proposed obstacle algorithm, a performance index is proposed in this paper. As shown in Fig. 4 (1), the direct linear path from the start position to the target position is the most efficient path for the movement in the view of time consumption and energy consumption. In this paper, proximity to the direct path is quantumized with equation (4). Where, l denotes the direct distance from the start position to the target position, d_1, d_2, d_3 denotes the maximum distance in each section, which are curves closed by actual path of the robot movement and the direct path.

$$p = (d_1 + d_2 + d_3) / l \quad (4)$$

The results of the performance index p with configured velocities are shown in Table 2. As shown in Table 2, the values of the performance index are always smaller with the proposed obstacle algorithm compared to the classical VFH. Through the quantumized results, the performance enhancement in the viewpoint of time consumption and energy consumption by the proposed algorithm is verified

Table 2. Performance Index for Proximity to Direct Path

Movement Velocity	40mm/S	50mm/S	60mm/S
Classical VFH	0.263	0.223	0.243
Proposed Algorithm	0.211	0.176	0.125

4. CONCLUSITIONS

In this paper, an obstacle avoidance algorithm adequate for a network-based autonomous mobile robot is proposed. The proposed obstacle avoidance algorithm is based on the VFH algorithm, and for the network-based robot system, in which it is assumed robot localization information is transmitted through network communication.

In this paper, target vector for the VFH method is estimated through the robot localization information and the measurement of its delay by distribution. The measurement is performed by time-stamp method. To synchronize all local clocks of the nodes distributed on the network, the global clock synchronization method is adopted. With the delay measurement, the robot localization estimation is performed by calculating the kinematics of the robot.

The validation of the proposed algorithm is performed through the performance comparison of the obstacle avoidance between the proposed algorithm and the existing VFH algorithm on the network-based autonomous mobile robot.

For further studies, studies on effector fusion and sensory fusion in the network-based autonomous mobile robot will be followed.

REFERENCES

[1] M. Mock and E. Nett, "Integrating Hard and Soft Real-Time Communication in Autonomous Robot Systems", IECE/IEEE Joint Special Issue on Autonomous Decentralized Systems of the IEICE Transactions on Communications, vol. E83-B, no.5, pp. 1067-1074, May 2000.

[2] Hongryeol Kim, Daewon Kim, HongSeok Kim, and Hogil Lee, "Toward the Personal Robot Software Framework", ICCAS Conf., pp. 2307-2312, 2002.

[3] Stergios I, Rouneliotis, "Distributed Multirobot Localization", IEEE Transactions on Robotics and Automation, Vol 18 No 5, Oct 2002.

[4] Andrew Howard, Maja J Mataric and Gaurav Sukhatme, "Relaxation on a Mesh: a Formalism for Generalized Localization", In Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2001), Wailea, Hawaii, Oct 2001.

[5] J. Borenstein, Y. Koren"The Vector Field Histogram -Fast Obstacle Avoidance for Mobile Robot", IEEE Journal of Robotics and Automation, Vol 7 No 3, pp278-288, June 1991.