A Number of Mobile Manipulator Control for Moving an Object by using Cooperative Control

Deok-Su Kim
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu Busan, 609-735, Korea Republic

Dong-Eon Kim
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu Busan, 609-735, Korea Republic

Seong-Ik Han
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu Busan, 609-735, Korea Republic

Jang-Myung Lee
Dep. of Electronic Eng., Pusan National University, Jangjeon-dong, Geumjeong-gu Busan, 609-735, Korea Republic

E-mail: deoksu1696@pusan.ac.kr, hyunuk.ha@gmail.com, dongeon1696@pusan.ac.kr, jmlee@pusan.ac.kr
www.pusan.ac.kr

Abstract

In this paper, we propose a method of cooperative control of a three mobile manipulator for moving an object. These robots go to desired position independently by using encoder data and inverse kinematics and after arriving in the position, they grasp and lift the object. For the carrying operation, the lifting operation is implemented by using the manipulator mounted on the top of the mobile robots cooperatively. In this system, master-slave mode is used for finding each position of robots and for coordinative control among the robots. During the moving operation, a trajectory planning has been kept constantly. The real cooperative carrying motions was implemented to check the possibility of the master-slave mode control based on the mobile manipulator's kinematics.

Keywords: Cooperative Control, Kinematics, Mobile Manipulator, Master-Slave.

1. Introduction

Due to rapid growth of the intelligent robot industry in the modern society, role of robot has been increased. so it is used in ordinary life as well as industries[1]. recent studies of mobile robot is extended from single action plan of a robot to cooperation of a number of robots.[2] the cooperation system with robots can solve impossible problems that can't do with performance of each robots.[3] to achieve goal in cooperative robotic systems, a strategy for the cooperation between robots is essential.

recently a theory of intelligent communities make it possible that solving complex missions by serving flexible way.[4] cooperative robot system is classified behavior control technology, situation recognizing technology, networking technology, clustering technology, and in this paper, we want to propose the overall system about cooperative robot. situation, and action is given, so we just investigated for moving and communicating method.

In this paper, we studied cooperative control for carrying an object by using three mobile manipulator. We suggest method of cooperative control for moving an object by using three mobile manipulator. and we explain the position control by using encoder value and trajectory plan after that we conclude this paper.

Fig. 1. Mobile robot.

2. Cooperative Control System

The robot in Fig. 1was made for experiment. for position control it use two motors and it was controlled by Embedded Computer. The manipulator is composed of three-wheeled and three-linked mobile manipulator system.

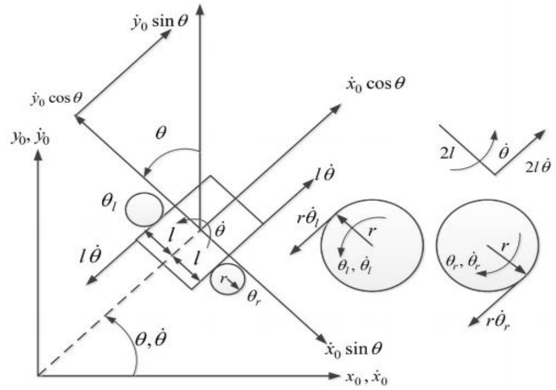

Fig. 3. Schematic description of a mobile part.

$$
\begin{aligned}
&+\frac{1}{2}m_2[\dot{x}-r_2\dot{\theta}_2 s\theta_2 c_{\varphi\theta_1}-r_2(\dot{\varphi}+\dot{\theta}_1)c\theta_2 s_{\varphi\theta_1}]^2\\
&+\frac{1}{2}m_2[\dot{y}-r_2\dot{\theta}_2 s\theta_2 s_{\varphi\theta_1}+r_2(\dot{\varphi}+\dot{\theta}_1)c\theta_2 c_{\varphi\theta_1}]^2\\
&+\frac{1}{2}I_{z2}[(\dot{\varphi}+\dot{\theta}_1)^2+\dot{\theta}_2^2]\\
&+\frac{1}{2}m_3[\dot{x}-l_2\dot{\theta}_2 s\theta_2 c_{\varphi\theta_1}-l_2(\dot{\varphi}+\dot{\theta}_1)c\theta_2 s_{\varphi\theta_1}-r_3(\dot{\theta}_2+\dot{\theta}_3)s\theta_{23}c_{\varphi\theta_1}\\
&-r_3(\dot{\varphi}+\dot{\theta}_1)c\theta_{23}s_{\varphi\theta_1}]^2+\frac{1}{2}m_3[\dot{y}-l_2\dot{\theta}_2 s\theta_2 s_{\varphi\theta_1}\\
&+l_2(\dot{\varphi}+\dot{\theta}_1)c\theta_2 c_{\varphi\theta_1}-r_3(\dot{\theta}_2+\dot{\theta}_3)s\theta_{23}s_{\varphi\theta_1}+r_3(\dot{\varphi}+\dot{\theta}_1)c\theta_{23}c_{\varphi\theta_1}]^2\\
&+r_3(\dot{\varphi}+\dot{\theta}_1)c\theta_{23}c_{\varphi\theta_1}]^2+\frac{1}{2}I_{z3}[(\dot{\varphi}+\dot{\theta}_1)^2+(\dot{\theta}_2+\dot{\theta}_3)^2].
\end{aligned}
$$

The potential energy is obtained as follows:

$$V=m_2 g r_2 s\theta_2+m_3 g(l_2 s\theta_2+r_3 s\theta_{23})$$

And we use Bumblebee stereo camera to detecting object and get depth information of it. We use triangulation algorithm which refers to the process of determining a point in 3D space given its projections over two or more images. Now, we recognize our mobile robot`s velocity, torque, object`s position and depth information. We propose an approach to control the communication among 3 mobile robots. In our system, 3 mobile robots which take role of clients are worked under the control of a computer server. Status data coming from mobile robot, which contains the information about robot`s position, orientation and end-effector`s posture, is transferred to computer. In server term, after collecting data from 3 robots, the programed calculation process is operated. The result of this process is the next status data for 3 mobile robots, is then sent to all slaves by using wireless communication. Our mobile robot system is set up with the architecture of sever & multi-client, which is include one computer and three autonomous mobile robots. Computer takes a role of server device, which is in charge of receiving the status of each mobile robot, and then, after calculation process, it send back the command to each client (mobile robot). In term of mobile robot, after sending the status containing the information about position of the platform and the angler of each link in end-effector, it will wait until receive the command from server. Depend on the data coming from computer, mobile robot will move to next position. In mobile robot, we use embedded system to control whole process. The device using in our experiment is IEC1000 series industrial embedded computer & HMI, which is supported to use external HNS wireless card. Schematic description of a mobile part(Fig.3), the dynamic equations of mobile robot is describe as the following equation:

$$\begin{bmatrix} \dot{x_o} \\ \dot{y_o} \\ \dot{\theta} \\ \dot{\theta_r} \\ \dot{\theta_l} \end{bmatrix} = \begin{bmatrix} \frac{r}{2l(lcos\theta - dsin\theta)} & \frac{r}{2l(lcos\theta + dsin\theta)} \\ \frac{r}{2l(lsin\theta + dsin\theta)} & \frac{r}{2l(lsin\theta - dcos\theta)} \\ \frac{r}{2l} & -\frac{r}{2l} \\ 1 & 0 \\ 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \dot{\theta_r} \\ \dot{\theta_l} \end{bmatrix} \quad (1)$$

- $q_v = [x_o \quad y_o \quad \theta \quad \theta_r \quad \theta_l]^T$: The generalized coordinates of the mobile platform.

Where

- x_o y_o :The position of mobile robot.
- θ : The rotation angler of mobile robot's pl atform.
- θ_r θ_l : The rotation angler of left wheel and r ight wheel, respectively.
- *r* : The radius of the wheels.
- *2l* : The distance between 2 wheels.

From eq.(1), if the desired velocity vector of the left and right wheel is given, the translational velocity, with respect to x-axis and y-axis respectively, and angular velocity of the platform is also specified. Consequently, after sending the status data (platform`s position and direction, end-effector`s posture) to computer, mobile robot is waiting for the command coming from computer, which contains the information about desired velocity of the left and right wheel. Client`s processor controls all other parts based on the data coming from server. Client-Server (CS) mode is an information sharing mode which is widely used in information system. The core of CS system structure is the distribution of task-level application between client and server. In the C/S system Clients and servers can be linked through LAN, WAN or internet. In client-Server module, it allows to share information and resource among the systems like files, disk space, processors and peripherals which can collaborate and deliver message inevitably between many processors. Therefore, The mechanism which get the other machine`s network address while communicating between network. A server (computer) maintains the communication with the three clients. Therefore, it is needed to apply several way to separate the mobile robot`s connection time between server. Therefore, in this case, multi-thread is applied for server programming. The key of the multi-thread create the main server socket object in the main program. As each client connects to the server, the main program creates a separate thread to handle the communication.

Many methods have been suggested for the control of autonomous mobile robot like behavior-based approach, virtual structural approach. To control the three multi mobile robots we used leading-follow approach and virtual architecture. Behavioral approach use the distance between the robot to control the other action like evasion, maintaining the position and the movement. It is mainly used when lots of robots search the space, it is easy to derive a control strategy when a plurality of tasks are given. Virtual structure approach is the method that as robots moving keep the charge point to maintain the specific structure. This method defines a desired virtual structure and convert the virtual structural movement to the path that robots move. Finally, leading-follow approach is a way to maintain the overall position by keeping the robot along a desired distance and angle tracking robots. In this paper, we decide the sequence of operations and make different behavior depending in the order of the conditions. The driving method will be different according to the robot is holding a object or not. Also, when lifting the object the movement of the robot is changing. It divided into three conditions to have a driving and the operation patterns for each situation. 1. The case that the robot does not holding an object. First, the mobile robot need the finding action to find the object. It use the bumblebee camera to identify the location through the object recognition. In addition, the starting position of the mobile robot is fixed point. So the first step is to access a place that exist the object to lift. The mobile robot that knows the target location and the start location is easily accessible to the target position. 2. When lifting the object. The robot knows the coordinates of the current location. To lift an object we set the manipulator movement by inverse kinematics analysis. We consider the approach distance of the mobile robot to the inverse kinematics analysis. 3. When mobbing with the holding object. After lift the object, three mobile robots should move in the same direction at the same time. Additionally, the distance and angle between the robot to be held constant. Three robot is composed of a single Master and two Slave robot. Master robot determine the each situation and receive communication information with the slave robot. A control algorithm of a robot can be seen from Figure 3.

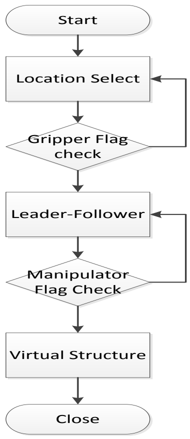

Fig. 3. Algorithm for swarm robots.

The first three robots must go to find their target position. If all three robot reaches the correct position, the robot takes an object with stretched arms. At that time the Slave robot sends the signal to determine the objects caught to the Master robot. When Master robot notice that three robots grab the object it will lift the object on. This algorithm inform to master robot that slave robot holding all of the objects and when master robot is holding the object is lifted on it will drive with maintaining the present distance and angle based on position of leader robot. Each of the conditions will be noticed using camera. Each robot is controlled by Embedded Computer. We can confirm that driving works well by using PD controller in the Encoder value.

Conclution

In this paper, we proposed the method of navigation of Mobile Robot using recognition and distance information with Bumblebee stereo camera. And controlling the communication which use Wifi-comm based on the socket programing applying wireless communication in

Fig. 4. Mobile Robots in formation based on the Vision.

three mobile robot system,. By applying structure of multi-thread server, computer can handle the communication with three mobile robots without collision. We deal with the multiple robot coordination control system using inverse kinematics analysis.

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