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Handling of a Single Object by Multiple Mobile Robots based on Caster-like Dynamics

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Abstract— **When we consider a coordination of multiple mobile robots, it is difficult to know the geometric relations among them. Errors in position and orientation of each robot detected by dead reckoning system are inevitable because of the slippage between wheels and the ground. To overcome these problems, in this article, we introduce a caster-like dynamics for controlling the multiple mobile robots in coordination. By using the caster-like dynamics, multiple mobile robots could handle a single object without using the geometric relations among them and the shape of the object. The effectiveness of the caster-like dynamics is illustrated through the video in which several types mobile robots handle a single object in coordination.**

I. Introduction

When we would like to move a large or a heavy object, which could not be handled by a human, we move it with other people or helpers. If a robot/robots could play a role of human helpers, we could move it without any help of humans. A robot helper is a robot, which plays a role of the human helper/helpers. The robot helper is expected to do tasks in an ordinary environment with humans.

Mobility is an important function to cover a working space in the environment. Multiple small robots are more appropriate for such a system than a large and heavy robot from safety point of view. Because each small robot has less kinetic energy than the large and heavy one, when they are moving with the same speed, and less harmful to a human when it collides with a human/humans. The distributed robot helper that we introduce in the video is a small mobile robot [1], and helps humans to carry an object together with other robot helpers as shown in Fig. 1.

Many researchers have proposed several kinds of motion control algorithms of multiple mobile robots for handling a single object. Most of these control algorithms have been designed under the assumption that the force/moment applied to a representative point of the object is available and/or geometric relations among the robots and the representative point are known precisely. However, it is not easy to know the geometric relations among them precisely, especially when the robots handle an object with unknown shape in coordination.

When we consider coordination of multiple mobile robots, it is much more difficult to know the geometric relations among them. Errors in position and orientation of each robot detected by dead reckoning system are inevitable because of the slippage between wheels and the ground. Even if we knew the geometric information of the object, the motion relations among the robots could not be kept precisely anymore because of the errors included in position and orientation information of each robot. To overcome these problems, in this article, we introduce a caster-like dynamics for multiple mobile robots which realizes the robust handling of the object by them without using the geometric relations among them and the shape of the object.

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Fig. 1. Human-Robots Coordination for Handling a Single Object

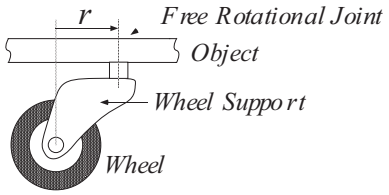

Fig. 2. Real Caster

II. Caster-like Dynamics for Mobile Robots

Let us consider the case where we move an object with multiple casters. A chair is a good example of such object. The caster has a mechanism attached to the chair through its free rotational joint as shown in Fig. 2. When a force/moment is applied to the chair by a human, the wheel of each caster rotates around the free rotational joint to the direction of the applied force, and then, the chair could move toward the direction. It should be noted that each caster does not need to know the geometric relations among casters.

If the grasping point of each mobile robot behaves as if it was a real caster, the manipulated object could move as if multiple casters supported it. With such concept, we

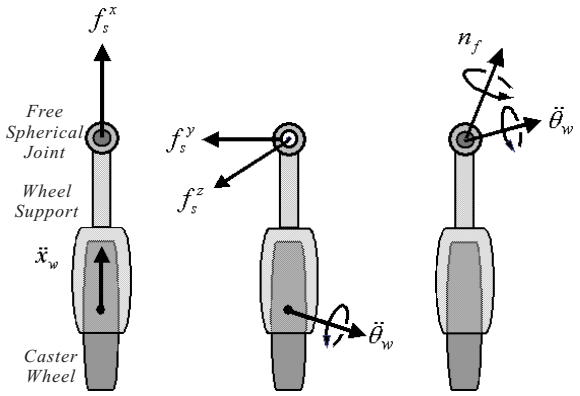

Fig. 3. Three Types of Virtual 3-D Caster Motion

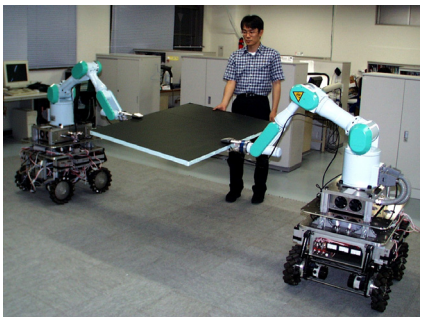

Fig. 4. Handling a Single Object in 3-D Space by Multiple Mobile Manipulators in Cooperation with a Human

have proposed a decentralized control algorithm for multiple mobile robots with a virtual caster to handle a single object in cooperation with a human on 2-D plane without using the geometric relations among robots [1].

III. Virtual 3-D Caser Dynamics for Mobile Manipulators

For realizing the manipulation of an object in 3-D space, we have also proposed the coordinated control algorithms of multiple mobile manipulators [2]. By extending the motion of the real caste on 2-D plan, we design the special caster-like dynamics referred to as virtual 3-D caster as shown in Fig. 3. Based on the concept of the caste-like dynamics, the human could handle a single object without considering the geometric relations among robots as shown in Fig. 4.

For realizing the object handling in 3-D space, we developed the mobile manipulators as shown in Fig. 4 and Fig. 5. Each robot consists of an omni-directional mobile base and one or two 7-DOF manipulators. The manipulator is PA-10, which is commercially available from Mitsubishi Heavy Industries Ltd. The six-axis force/torque sensor is installed to the wrist part of each manipulator. The system is controlled by an on-board PC-compatible system, powered by on-board rechargeable battery and connected to the network system of our laboratory through the wireless Ethernet.

In the coordination between the manipulator and the mobile base of each mobile manipulator, the end-effector

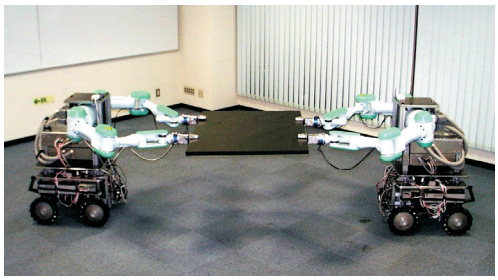

Fig. 5. Leader-Follower type Motion Control Algorithm for Multiple Mobile Robots with Dual Manipulators Handling an Object

of the manipulator is controlled based on the caster-like dynamics with respect to the world coordinate system. And the apparent impedance of the mobile base is also specified relative to a coordinate system, which is kept with constant pose displacement from the pose of the end-effector of the manipulator. By using this control algorithm, multiple mobile manipulators could handle the object without being disturbed by the motion of the mobile base, even if the mobile base avoids the obstacles autonomously by using information from the external sensors.

We also realize leader-follower type motion control algorithm by using the caster-like dynamics as shown in Fig. 5 [3], [4]. The desired trajectory of the object is given to the one of mobile manipulators, which is the leader robot, and applies the force to the object based on the desired trajectory. The other robots referred to as follower are controlled so as to have a virtual 3-D caster dynamics and estimate the desired trajectory of the leader along the heading direction of the virtual 3-D caster.

IV. Conclusions

In this article, we introduced a caster-like dynamics for controlling multiple mobile robots in coordination to handle a single object. By using the caster-like dynamics, multiple mobile robots could handle a single object without using the geometric relations among robots and the shape of the object. This kind of coordination is very effective for using the mobile robots in the real world environment.

References

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