Extended Abstract

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An Experimental Study on the Cooperative Transportation of a Load Using Swarm Robots

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Cooperative transportation of a load is an application of swarm robotics in which a swarm of mobile robots creates a formation around an object and transports it toward the desired target. This task is usually done by prehensile and non-prehensile approaches. In prehensile approaches, the robots and the load are rigidly connected, for example by a gripper, and force closure techniques are considered which ensure that the grasp can resist any external force applied to the object. In non-prehensile approaches, the load is carried by pushing or rolling and the contact forces and stabilization of the movement direction are studied.

Instead of the mentioned methods, we propose a new approach where a formation of omnidirectional mobile robots transports a plate purely by normal and friction forces between the robots and the load [1, 2, 3]. The load is an elastic plate and has contact with the pins that are attached to the top of the robots. There are no closure forces to grasp the plate or pushing forces. The absence of rigid connection gives the robots the ability to move and stick or slip under the load, and thus, change the respective force direction and position. This change of robots positions and the associated driving forces can be utilized to achieve the desired motion of the swarm and the load. If more than three robots are under the plate, the system is overdetermined. Further, the displacement constraints at the contact points are unilateral. Hence, a linear complementary approach is used in order to calculate the normal forces.

In this contribution, the transportation is tested in a hardware experiment to study the slip and stick effects between the load and robots. To prepare the experimental setup, a vision based object localization of a multi-agent system using augmented reality is developed and the communication between the mobile robots is facilitated by the Robot Operating System (ROS). Figure 1 shows the transportation of an elastic plate made by transparent plexiglas which make the localization possible. Mobile robots are marked with characters in order to distinguish them from each other. This figure shows that the pin has unilateral contact with the plate and a robot can move easily under the plate.

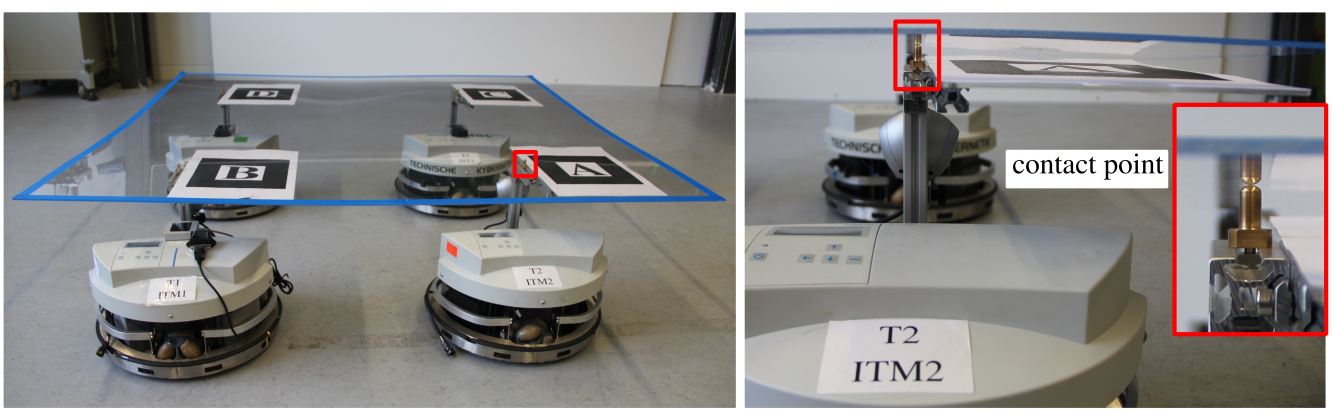

Fig. 1: Experimental setup.

By using this type of manipulation mechanism, relative movements of the robots and highly dynamic driving maneuvers of the robots will sometimes lead to a sliding plate, resulting in a displacement between the formation center and the center of the plate. In the worst case, this may lead to an instability of the system, where the plate falls off the robots. Considering this, the contribution investigates the stability of the plate. To this end, we investigate the slip and stick effects in various scenarios to identify the system parameters for example the friction coefficient between the pin and the plate. The scenarios include the highly dynamic driving maneuvers of the robots, e.g., a strong acceleration of the formation or motions around a sharp corner. Using the results, the system parameters are updated and are used for the further research.

The swarm can be utilized to transport an elastic plate also in complicated conditions like in Figure 2 where there is a narrow passage that just one mobile robot can pass at a time. To reach the target, a formation of omnidirectional mobile robots follows a virtual leader which is shown by red color by using the artificial potential field method. They avoid obstacles by using sensory data and the formation is changed based on the environment. Although the passage is too narrow for the swarm as a whole, the mobile robots use an intelligent mechanism to reorganize themselves to pass it while they simultaneously keeping the stability of the plate.

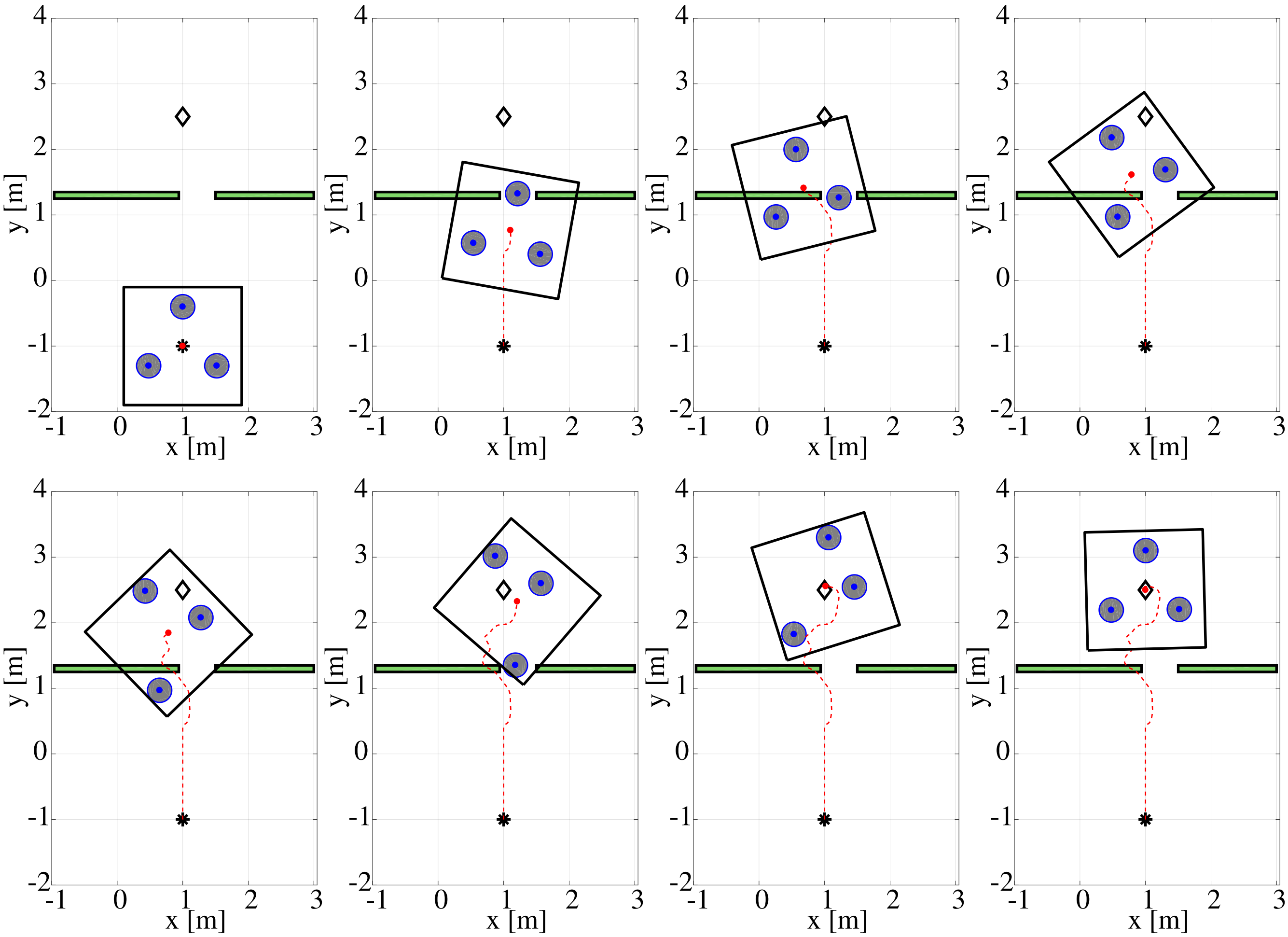

Fig. 2: Transporting a load through a narrow passage.

References

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