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Coordinated Pose Control of Mobile Manipulation with an Unstable Bikebot Platform

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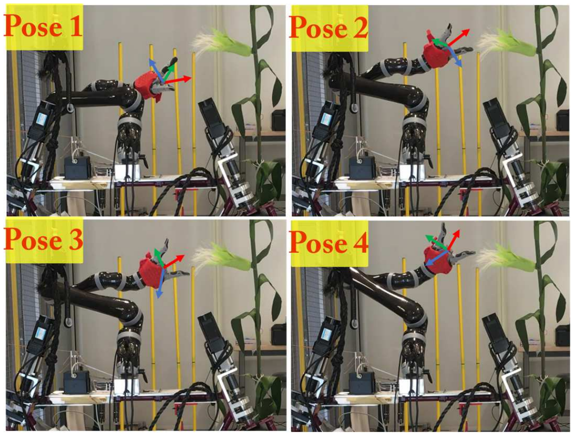

Fig. 1: Snapshots of the manipulator with an inspected plant.

***Abstract*—Bikebot manipulation has advantages of the single-track robot mobility and manipulation dexterity. We present a coordinated pose control of mobile manipulation with the stationary bikebot. The challenges of the bikebot manipulation include the limited steering balance capability of the unstable bikebot and kinematic redundancy of the manipulator. We first present the steering balance model to analyze and explore the maximum steering capability to balance the stationary platform. A balancing equilibrium manifold is then proposed to describe the necessary condition to fulfill the simultaneous platform balance and posture control of the end-effector. A coordinated planning and control design is presented to determine the balance-prioritized posture control under kinematic and dynamic constraints. Extensive experiments are conducted to demonstrate the mechatronic design for autonomous plant inspection in agricultural applications. The results confirm the feasibility to use the bikebot manipulation for a plant inspection with end-effector position and orientation errors about 5 mm and 0.3 degs, respectively.**

***Index Terms*—Underactuated robots, balance control, mobile manipulation, task priority planning, bicycle control**

Mobile manipulation integrates a mobile robot with an onboard multi-link manipulator to expand workspace and improve capability for complex manipulation tasks. The advantages of the mobile manipulation come at the cost of coordinated planning and control. Coordinated planning and control is critical when the mobile platform is unstable or in complex, dynamic environments. Balance control of unstable platform is among the highest priority tasks for mobile manipulation. For kinematic redundant manipulators, task-priority control takes advantages of design space in the null space of the Jacobian matrix. Velocity control was designed through optimization to satisfy the control tasks from the highest to lowest priorities.

In this paper, we present a mobile manipulation system that is built on an autonomous bikebot. A 6-DOF manipulator is mounted on the bikebot and the system was developed for agricultural applications. We focus on stationary balance of the bikebot manipulation. It is more challenging to balance a stationary bikebot than a moving platform and many applications such as plant inspection require that the mobile platform stays stationary.

We present the coordinated control to enhance the stationary balance and posture control task. A steering balance model is presented to analyze the steering configuration and maximize the balance capability. The balance condition is captured by an extended balance equilibrium manifold (BEM) of the mobile manipulation system. A BEM-enabled coordinated trajectory planning and control design is presented to achieve a balance-prioritized posture control. The proposed coordinated motion control design integrates the dynamic balance requirements with the task priority-based planning of a kinematic redundant manipulator. The experimental results show that the position errors are at the same level of the manipulator hardware performance limits (3.7 mm) that are provided by the vendor and the orientation errors are much less that level (2.1 degs). The results demonstrate the successful balance and pose control performance by the design.

Several ongoing research directions are considered to further improve the system performance. It is of interests to use steering dynamics to improve the control performance. Incorporation of the manipulator dynamics into the BEM might further improve and achieve agile balance tasks that are desirable in applications.

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