Chapter 2
Design, Analysis, and Applications of Mobile Manipulators

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ABSTRACT

Presented in this chapter is a method for design and analysis of a mobile manipulator. The wrench induced by the movement of the robot arm will cause system tip-over or slip. In tip-over analysis, three cases are considered. The first case deals with the effect of the link weights and tip payload on the horizontal position of the CG. The second case deals with the effect of the joint speeds through the coupling terms including centrifugal forces and gyroscopic moments. The third case deals with the effect of the joint accelerations through the inertia forces and moments. In slip analysis, the first case considers the reaction force in relation to the stand-off distance between system and work-piece. The second and third cases investigate the effects of the joint speeds and accelerations. Then, the mobile platform is optimized to have maximum tip-over stability which optimizes the placement of the robot arm and accessory on the mobile platform. The effectiveness of the proposed method is demonstrated.

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INTRODUCTION

A mobile manipulator integrates a mobile platform with an onboard robot arm called manipulator. Such a combined system is capable of executing manipulation tasks in a much larger workspace than that of a fixed-base manipulator. This combination offers the dexterous manipulation capability from the manipulator as well as the mobility from the mobile platform (Liu & Liu, 2010).

Mobile platforms can be classified as: tracked, legged, and wheeled. A tracked mobile manipulator has improved traction than other two due to a larger contact area with ground, making it ideal for working under unstructured environment for searching, rescuing, explosive ordnance disposing, mining, logging, farming, earth moving and planetary exploring (Liu & Liu, 2009). A legged mobile manipulator has the ability to step over obstacles along a moving path, uniquely suited for overcoming complex indoor environments including furniture, walls, stairs, doors, as well as outdoor environments that may be of rough terrain and uneven surfaces (Rehman, Focchi, & Lee, 2016). A wheeled platform, on the other hand, can move at a high speed on an even and solid surface in structured environments such as factory, store or home (Vysin & Knoflicek, 2003). This chapter deals with the wheeled manipulator used for manufacturing, such as drilling, riveting or line drawing.

For a wheeled mobile manipulator, the wrench exerted by the manipulator onto the mobile platform will affect the system performance. These effects include tip-over or/and slip which are not considered for the fixed-base counterpart. Tip-over issue is of great concern for the safety of robot operation. The occurrence of slippage will lead to the loss of posture accuracy, thereby affecting manufacturing quality. The avoidance of these two issues should be studied in two aspects. The first one is to study the effect caused by the dynamics parameters of the manipulator to gain insights on the interaction with the mobile platform. Then the second one is to optimize the mobile manipulator system in order to obtain the maximum stability margin. In what follows, the details are provided.

WRENCH MODELING

Manipulator Kinematics

Figure 1 shows a kinematic model of the manipulator under this study. The method presented in (Xi, 2009; Lin, Xi, Mohamed, & Tu, 2010) is used here for kinematic modeling. This method formulates the manipulator kinematics through two parts. The first is a static part to represent the initial configuration of each link and the second is a motion part to represent the movement of each joint. For the static part,