Abstract

Today's stability criteria are not capable for providing a precise definition and precaution suited for a mobile robot: traversing on unpredictable surface, exerting manipulation forces and torques, susceptible for variable ground normal forces, or subjecting to attitude orientations. Thus, this research firstly examined the dynamic effects of mobile robot traversing on different surface geometries with variable configurations and attitudes, and it secondly investigated their impact on the normal forces distribution. Finally, it reflected the influences of these factors on the dynamic stability of the rover in order to protect the rover from tumbling. This study presents a new dynamic stability criterion done on a new mechanical structure; quadruped mobile robot equipped with wheels and legs called rover.

The primary contribution of this thesis is exploiting the Denavit-Hartenburg approach for assigning the coordinate frames at link's end-terminals, and then relating between each two adjacent frames by forming homogeneous transformation matrix. Forward kinematics is exploited to relate the end-effectors (four wheels) with base frame (platform). The platform attitudes (Roll, Pitch, and Yaw) are evaluated in relative to proposed universal frame at the center of platform. The coordination between locomotion (wheels' motion) and manipulation (joints' motion) is clearly defined.

In this work, the dynamic equations of motion are driven by using Newton-Euler Recursive Relations. The kinematics of links (velocities and accelerations) are propagated in forward recursion starting from base frame and ending at the four end-effectors, link by link. As well as, the dynamics of links (generalized forces and moments) are propagated in backward recursion starting from four end-effectors frame and ending at base frame, link by link. The force and moment propagated into a base link (platform) are determined as a

function of gravity forces, inertial forces, inertial toques exerted on the center of mass of links, and ground normal forces exerted on the end-effectors.

The equations of equilibrium for four legs are considered indeterminate system, thus in this thesis the normal forces are evaluated for three contact legs in the case the non-symmetric rover. However, in the case of symmetric configurations the normal forces are distributed equally between the sides which sharing the same the inertial forces, ground geometries, and platform attitude. Thus regarding to symmetric four legs are evaluated by considering two legs sharing the same value.

A new dynamic stability criterion is presented for rover in this thesis, and it is operating on various shapes of surfaces, and variable rover configurations. In addition, this criterion provides on-line calculations for the effect of variable rover configurations, various surface geometry, platform attitudes, kinematic values, dynamic effects, and variable ground normal forces. The on-line calculations are referred relatively to the universal frame.

The simulation model is also presented for various examples using MatLab in order to provide on-line calculations for predicting the behavior of a physical system under a variety of surface geometries and rover configurations.

Keywords: mobile robots, center of mass, static and dynamic stability margin, forward and inverse kinematics, forward and backward dynamics, wheeled-legged manipulator, uneven terrain, inertial forces and moments, inertial acceleration, normal and frictional forces, Newton-Euler Recursive Relations.