Proceedings of the 2005 IEEE
International Conference on Robotics and Automation
Barcelona, Spain, April 2005

Dynamic Stability of a Rocker Bogie Vehicle: Longitudinal Motion*

Moshe P. Mann
Department of Mechanical Engineering
Israel Institute of Technology
Haifa, Israel
moshem@yosh.ac.il

Zvi Shiller
Department of Mechanical Engineering-Mechatronics
The College of Judea and Samaria
Ariel, Israel
shiller@yosh.ac.il

***Abstract*— This paper describes a unified measure of stability of a Rocker Bogie vehicle that accounts for the tendency to slide, tipover, or lose contact with the ground considering both static equilibrium and dynamic effects. The measure of stability is computed by solving for the range of acceptable velocities and accelerations that satisfy a set of dynamic constraints. The maximum acceptable velocity serves as a dynamic stability measure, whereas the maximum acceptable acceleration at zero velocity serves as a static stability measure. The utility of the static and dynamic stability margins are demonstrated for both two dimensional and longitudinal quasi-3D motion in several examples.**

***Index Terms*— Mobile Robots, Motion Planning, Stability Margins, Rocker Bogie**

I. Introduction

The current robotic mission to Mars demonstrates the importance of autonomous off road vehicles [3]. Autonomous motion requires great care with regard to stability - both static and dynamic. Current literature on off road vehicles [7], [3] emphasizes static stability, which assumes low speeds. This, however, is insufficient for even current (low speed) rovers since motion on highly uneven terrain pose an instability risk even at low speeds, as demonstrated in this paper.

Several vehicle stability margins have been previously proposed. McGhee and Frank [6] defined a stability criterion for walking vehicles, their criterion being the projection of the center of mass being inside the support polygon. Papadopulos and Rey [7] use a static stability measure of the angle that the net force vector subtends with the line connecting the various tipover axis with the center of mass, with the criterion of stability being that the larger the angle, the more stable the vehicle. Garcia *et al* [4] presents a comparative study of several dynamic stability margins. These margins, while addressing dynamic situations, do not involve any dynamic properties *per se*, and do not indicate any uniquely dynamic properties about the robot, and hence they are not dynamic measures in the sense that this paper addresses.

*This work is partly supported by grant 01-99-08430 of the Israeli Space Agency through the Ministry of Science Culture and Sports of Israel

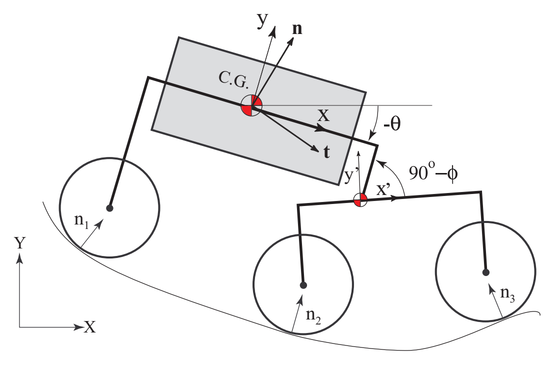

Fig. 1. Rocker bogie vehicle

In this paper, a unified stability margin is developed that accounts for static and dynamic stability of a rocker bogie vehicle. It is based on vehicle kinematics and dynamics and on terrain topography, similarly to the approach presented in [9], but extended to a rocker bogie vehicle [2]. The static stability margin indicates stability at zero speed, and the dynamic stability measure indicates the maximum allowable speed of the vehicle. The new stability margins are demonstrated in several examples for a Rocky-Bogie vehicle traversing a hill and climbing a step.

II. 2D Vehicle Model

The Rocker Bogie is a six-wheel all-terrain off-road vehicle [2], consisting of a main body with each side connected to a different chassis, known as a rocker. The back of each rocker has one wheel, while the front is connected to another chassis (the bogie) with two wheels each via an unactuated pitch joint. This section deals with the two dimensional analysis of the vehicle.

Referring to Figure 1, the distance from the center of mass to the back wheel is the vector $\mathbf{r_1}$, and to the pitch joint is $\mathbf{r_2}$, expressed in body frame coordinates, with all wheels having radius r. The distance from the pitch joint to the front chassis' back wheel is $\mathbf{d_1}$, and to its front wheel is $\mathbf{d_2}$, expressed in body frame coordinates. Referring to Figure 2, the rocker makes an angle θ with the world, and ϕ is the angle that the front chassis makes with the body