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Planar Trajectory Planning for a Small Tracked Unmanned Ground Vehicle (SUGV)

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Abstract

In this paper, a method for trajectory planning for a Small tracked Unmanned Ground Vehicle (SUGV) in many specified paths is presented. The Planar motions of tracked vehicles are mostly described by three force and moment equations with two independent control input variables. A dynamic nonholonomic constraint is represented with force equation perpendicular to the tracks which is definitely dependent on vehicle speed and couples path planning of the vehicle with the trajectory planning. Calculation of required angular velocity of sprocket and also nominal track forces of vehicle is also presented so that the vehicle follows a specified path at desired speeds.

Keywords: Small Unmanned Ground Vehicle, trajectory planning, path planning, dynamic nonholonomic constraint, track forces

Introduction

Tracked vehicles are more useful in applications those demand off-road mobility, than wheeled vehicles. Because of large contact area with the ground, tracked mechanisms provide better floatation and better off-road crossing at various ground conditions [1].

Tracked mechanisms are therefore the proper choice for autonomous mobile robots which require off-road mobility to perform many tasks such as military, agricultural, rescue, mining, planetary exploration and recreational applications where terrain conditions are harsh or unpredictable. In recent years, increasing attention has been devoted to rescue and reconnaissance robots, both from the research community and from the rescue operators.

Tracked unmanned ground vehicles are now in fashion in military applications. Thousands are in use in Iraq and Afghanistan in military use, mostly as short range scouts to inspect possible bomb sites - a task very similar to the one of police robots since many years [2]. iRobot “Packbot” and Foster-Miller “TALON” are the most popular military tracked robots those are deployed widely in US armed forces. “Desert Hunter” is a military tracked robot developed in Isfahan University of Technology for surveillance, reconnaissance and battlefield applications (see Figure 1)[3]. “HIRAD” is also a mobile tracked robot that is designed and manufactured in Isfahan University of Technology for multitask operations (military/rescue).

Robots can consistently help humans in dangerous tasks during unmanned reconnaissance and rescue operations in several ways [4]. An unmanned reconnaissance scenario is usually unstructured and unstable, thus requiring the use of complex mechanical and locomotive design of the robots involved. On the other hand, communication unreliability and the difficulty of direct control of complex robots require some degrees of autonomy.

Figure 1: Desert Hunter: Military tracked robot for surveillance and reconnaissance applications

Control of tracked vehicles is more complex than in differential drive wheeled vehicles because of the skid steering principle: variation of the relative velocity of the two tracks results in slippage and soil shearing in order to achieve steering. So it is not possible to predict the exact motion of the vehicle only from its control inputs. The motion of wheeled vehicles is, therefore, constrained by a non-integrable differential kinematic constraint which is independent of vehicle speeds. This permit separating the vehicle motion planning into path planning (computation of the geometric path) and trajectory planning (computation of velocity profile along the path). In contrast, tracked vehicles are maneuvered by skid-steering. Their motions are therefore constrained by a non-integrable dynamic constraint. This constraint makes the path planning of the vehicle coupled with the trajectory planning. Therefore, motion planning of tracked vehicles is more difficult than wheeled systems. The dependence of track vehicles motion on ground forces led to extensive research on terramechanics [5-9].

In this paper a method for motion planning of a Small Tracked Unmanned Ground Vehicle (SUGV) along many specified paths is presented. HIRAD, a