



Finite-time control for soft landing on an asteroid based on line-of-sight angle

Qixun Lan^{a,b}, Shihua Li^{a,*}, Jun Yang^a, Lei Guo^c

^a*School of Automation, Southeast University, Nanjing 210096, PR China*

^b*School of Mathematics and Physics, Henan University of Urban Construction, Pingdingshan 467036, PR China*

^c*Institute of Instrument Science and Opto-Electronics Engineering, Beihang University, Beijing 100083, PR China*

Received 19 September 2012; received in revised form 27 May 2013; accepted 13 August 2013

Available online 13 September 2013

Abstract

Motivated by the requirement for safe and pinpoint soft landing in future asteroids missions, a soft landing control method based on finite-time control (FTC) technique is developed in this paper. Firstly, in order to utilize the design philosophy of cascaded system, the landing error dynamics of asteroid probe are divided into two subsystems, including a position error subsystem (PES) and a line-of-sight angle error subsystem (LOSAES). Secondly, homogeneous system theory is employed to design the control law for LOSAES such that the states of LOSAES will be stabilized to the origin in finite time. For the reduced PES subsystem, a FTC law is designed such that the rest of states will converge to zero in finite time. Strict analysis shows that the whole system satisfies the finite time stability. Simulation results demonstrate that the proposed method provides faster convergence rates and better disturbance rejection properties compared with the traditional asymptotically stable control (ASC) method.

© 2013 The Franklin Institute. Published by Elsevier Ltd. All rights reserved.

1. Introduction

With the rapid development of modern science and technology, asteroid exploration provides a new way to study the origin of the universe and the physical formation of planets. It is reported that, in addition to analyze soil and rock chemistry, the probe will be able to measure carbon isotope ratios and so to help decide whether asteroids once supported life [1], thus soft landing on a celestial object is a key step for exploration on celestial objects.

*Corresponding author. Tel.: +86 25 83793785.

E-mail address: lsh@seu.edu.cn (S. Li).

Recently, mission feasibility studies and trajectory analysis have been conducted to assess the possibility of a rendezvous with celestial objects such as the moon, comets and asteroids. Significant challenges exist in the landing systems control design on celestial, such as dynamics with significant nonlinearities, cross-coupled terms, state and trajectory constraints, and parameter uncertainties [2–5,11], and so on. However, there are still some results [2–9]. Control parameterization method in conjunction with a time scaling transform is employed for soft landing problem of a moon lander [2], where an optimal control law is proposed to ensure the soft landing of the moon lander with least fuel consumption. By using control parameterization technique and a time scaling transform, an optimal guidance law and the corresponding optimal descent trajectory are obtained for lunar module soft landing problem, such that the desired trajectory is tracked with minimized fuel consumption and time [3]. Simulation environment and autonomous control algorithm for landing on comets are investigated in [4,5]. For the soft landing on an asteroid problem, the desired descent altitude and velocity should satisfy the requirement of soft landing, thus by properly selecting the desired trajectory the landing process can be transformed into a tracking control problem. Based on line-of-sight angle a two-dimensional celestial object system model is studied in [6]. By sliding mode control (SMC) technique and boundary layer method a guidance control law is proposed such that the tracking performance is achieved with an exponential convergence rate and the classical chattering drawback is alleviated. And this method is developed to design a three-dimensional guidance law for the rendezvous of a space vehicle with a celestial object in [7]. An autonomous optical navigation and guidance method is proposed, which extracts visual small features from the images taken by the navigation camera and tracks them robustly and accurately [8]. In [9], an autonomous optical navigation based on unscented Kalman filter is presented to satisfy the accuracy requirement of the guidance control law, and a guidance algorithm based on SMC is presented to ensure fast and accurate convergence property in the presence of parameter uncertainties and external disturbances. By using qualitative analysis method, the problem of power limited soft landing on an asteroid is studied in [10], and an optimal acceleration is proposed to ensure the probe vertical landing on the asteroid. Ref. [11] presents the guidance issues for the lunar pinpoint soft landing problem, and a polynomial guidance law is designed by using the Pontryagin maximum principle.

Note that almost all of these results about soft landing on celestial object only concern the asymptotic stability of the closed-loop tracking error system which means the convergence of states error system with an infinite time. Obviously, the guidance control laws with finite-time convergence are more desirable for landing dynamic systems. The reason is that, besides faster convergence rates, the closed-loop systems under finite-time control (FTC) laws usually demonstrate higher accuracy and better disturbance rejection properties [12,13,16,23,24].

Due to the above-mentioned prominent properties, FTC has received more and more attentions [12–27] in recent years. Finite-time Lyapunov stability theorems are proposed in [14]. These results provide a basic tool for designing continuous finite-time control laws. By using finite-time Lyapunov stability theory, FTC laws are proposed for the double integrator in [13], and finite-time output feedback stabilizers are also derived for the double integrator in [12]. Based on adding a power integrator method [16], another FTC method is proposed to study the global finite-time stabilization by output feedback for planar systems without controllable/ observable linearization [19]. Motivated by adding a power integrator technique, a global FTC law is designed for uncertain nonlinear systems that are dominated by a lower-triangular systems [21]. Later, adding a power integrator method is developed to solve global finite-time stabilization problems of feedforward systems in [20]. The other FTC method is nonsingular terminal sliding

Download English Version:

<https://daneshyari.com/en/article/4975421>

Download Persian Version:

<https://daneshyari.com/article/4975421>

[Daneshyari.com](https://daneshyari.com)