Chapter 1
Visual Servo Kinematic Control for Robotic Manipulators

Zheng Hong Zhu
York University, Canada

Gangqi Dong
Northwestern Polytechnical University, China

ABSTRACT

In the last couple of decades, massive industrial application demands greatly accelerated the advances of control theories for robotic manipulator. However, the autonomous robotic capture is still facing many technical challenges. A novel visual servo kinematic control scheme for robotic manipulators to perform autonomous capture operation of a non-cooperative target is presented. An integrated algorithm of the photogrammetry and the adaptive extended Kalman filter is introduced to estimate the position and orientation of the target. In order to improve the reliability of the robotic control and to avoid the multiple solutions problem of inverse kinematics, a kinematics-based incremental control approach is adopted to control the robotic manipulator in real time. Validating experiments are performed on a custom built robotic manipulator with an eye-in-hand configuration. The experimental results demonstrate the effectiveness and robustness of the proposed control visual servo kinematic control scheme.

DOI: 10.4018/978-1-5225-5276-5.ch001

INTRODUCTION

Due to increasing requirements of efficiency, dexterity and autonomy, robotic manipulators have been extensively employed in industrial and other applications to perform tasks that are monotonous, complex, dangerous, or even impossible to be conducted by human beings (Yoshida, 2009). Researchers have dedicated considerable efforts on design, modeling and control of robotic manipulators to accomplish many different kinds of missions, where autonomous capturing is considered as one of the key functions and with great engineering potentials not only in industrial applications but also in space missions (Larouche et al, 2014; Huang et al, 2016; Yu et al, 2016; Zhang et al, 2017).

The task of autonomous robotic capture of non-cooperative targets is not trivial. Although numerous enabling techniques have been proposed, autonomous robotic capture is still very challenging. Especially in space applications, the autonomous capture related techniques attract more attention than others. A preliminary concept design of guidance, navigation and control architecture was proposed in (Jankovic et al, 2015) for a safe and fuel-efficient robotic capture of a non-cooperative target in active debris removal missions, where the capture process was divided into three phases: orbital rendezvous, proximity maneuver and robotic capture. Since the autonomous orbital rendezvous and proximity maneuver are mature technologies and have been successfully performed in many other space missions, researchers mainly focus on the final autonomous capture stage of a non-cooperative target by space robotic manipulators. A vision-based prediction and motion-planning scheme was introduced in (Aghili et al, 2012) for robotic capturing of free-floating tumbling objects with uncertain dynamics. An attitude takeover control approach was proposed in (Huang et al, 2016) to stabilize the reconfigurable spacecraft in post-capture of target by space robotic manipulators. However, according to the recent study by Flores-Abad et al. in (Flores-Abad et al, 2014), the up to date successful space missions with the participation of robotic manipulator, such as active debris removal and on-orbit servicing, mainly relied on the human-in-the-loop control to gain higher reliability. In fact, the control problem of space robotic manipulators with free floating base is somewhat equivalent to ground ones with fixed base, enabled by generalized Jacobian matrix (Umetani et la, 2010), virtual manipulator (Vafa et al, 1987) and dynamically equivalent manipulator (Liang et al, 1998) technologies. In order to focus on the robotic control problem, the presented approach is performed on a fixed-base manipulator to prove the concept of the presented control scheme. Additional efforts, such as replacing the Jacobian matrix in the current kinematic approach with a generalized Jacobian matrix, or mapping the kinematics of a free floating manipulator to a fixed-base manipulator, may be required to apply the presented approach to free floating base space robotic manipulators.