CONCLUSIONS

The TSR is a novel kind of space robot, which consists of a gripper, a space tether, and a space platform. Due to its flexibility and great workspace, the TSR has wide applications in future on-orbit services including on-orbit maintenance, on-orbit refueling, auxiliary orbit transfer, and space debris removal. The dynamic model, target measurement, and coordinated control of the TSR are introduced in this book.

1. Dynamic models that are based on the Bead model, Newton-Euler, Lagrangian method, Finite Element method, and Hamiltonian method are studied in this book. Each different method has unique advantages for different purposes. The model of massless links is too simple to describe the characteristics of a TSRS. Although the Ritz method and Galerkin method are efficient for computation, their accuracy is not guaranteed due to the man-made global modal function. The finite element method is extremely precise to the real model and is considered to be a promising method to solve tether issues, even though it is rather complicated and unstable. As a classic dynamics model for a space tether, the Bead model enjoys widespread use due to its simple derivation and stable computation in the deployment and retrieval phase in the face of its low computational speed.
2. A visual perception system for the TSR's automatic rendezvous from 100 to 0.15 m is proposed in this book, which uses the binocular stereo vision. Considering that the shape of target satellite's main body can be cubical, polyhedral, or cylindrical, such a satellite can naturally be imaged by optical sensors. When the target satellite is coupled with advanced image processing and estimating algorithms, it achieves cost-effective and accurate sensing capability to capture and track the target in time to obtain the full 6 DOF relative pose information during the proximity operation. We design the detailed algorithm during the whole approach, including the tracking of the target contour, detection of the ROI, visual servoing, and pose measurement in far and close range.
3. Target approaching control is one of the most important problems for the TSR and several control methods are explored in this book. Given the fuel consumption of the TSR during the target approaching phase, coordinated schemes including "thrusters, space tether, reaction wheels," and "thrusters, space tether, mobile attachment point" are considered to minimize fuel

consumption. Besides, factors such as the distributed mass of the tether and the relative motion among platform, target, and gripper are also investigated and corresponding control methods are presented. In addition, with the consideration of the releasing mechanism of space tether characteristics, an easily achieved coordinated coupling position and attitude control law is designed.

4. Target capture is the key mission for on-orbit service of the TSR and the stabilization control problem of the TSR during target capture is studied. Given the structure of the TSR's gripper, an adaptive target capture controller based on impedance control is proposed, where the neural network is used to estimate the uncertainties in the dynamic model of the TSR and an adaptive robust controller is designed to track the desired position. After the target capture, the tumbling tethered space robot–target combination needs to be stabilized. Given the limitation of the control torque of the thrusters and the fuel of the gripper, an attitude-coordinated controller of the tether and the thrusters is designed to stabilize the combination and reduce the fuel consumption at the same time.

The authors wish to thank the readers for their patience. We hope that the book will not only broaden your horizons, but will also arouse an interest in further study of the TSR.