Proceedings of the International Conference on Mechanical Engineering and Mechatronics
Ottawa, Ontario, Canada, 16-18 August 2012
Paper No. 209

Motion Planning for a Multi-Segment Continuum Robot

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Abstract – Motion planning and redundancy resolution of a multi-segment continuum robot is studied. The direct and inverse kinematics model of the robot is derived assuming a constant radius of curvature in each flexible segment of the robot. Due to the primary and secondary backbone structure of the segment, each segment is modelled by two configuration variables and three joint space variables. This introduces both kinematics and actuation redundancy in the system. Kinematic redundancy of the robot is resolved through a closed loop Jacobian pseudo inverse technique, completed with the damped least square technique for singularity robustness provision. Furthermore, an improved Jacobian based motion planning is introduced which optimizes a predefined cost function corresponding a given secondary task. The methods are implemented both numerically and experimentally and accuracy and errors of the results are analyzed.

***Keywords*:** Continuum Robot, Motion Planning, Redundancy Resolution, Jacobian Pseudo Inverse Method, Damped Least Square Method

1. Introduction

Continuum or continuous backbone robots have been recently received a good attention by researchers. Continuum robots are inspired by invertebrate structures which are found in the nature such as biological tongues, trunks, and tentacles (Trivedi et al., 2008). Unlike the traditional rigid-link robot manipulators, continuum robots provide their motion by deformation of flexible parts. Continuum robots offer some distinctive features compared to traditional rigid link robots such as inherent compliance, reduced weight, fault tolerance, and whole arm manipulation capability. These robots can search inside confined spaces much easier than traditional rigid link robots. They exhibit improved performance in the areas of obstacle avoidance, compliant operation, and navigation in highly unstructured and narrow environments (Godage et al., 2011). Continuum robot applications in the areas of nuclear (OC Robotics, Web-1), medical surgical procedures (Haiyan et al., 2011; Reiter et al., 2011), and rescue tasks (Tsukagoshi et al., 2001) have become increasingly popular nowadays. Just like an elephant which picks up a log with its trunk, a continuum robot can picks up any object by wrapping itself around it.

Unlike traditional rigid-link robots, continuum robots are more complex to model, design, and construct due to their lack of rigidity. In recent years, significant progress has been made in the modeling of the continuum robots. General kinematics models of these robots have been developed by (Chirikjian and Burdick, 1994; Gravagne and Walker, 2000; Jones and Walker, 2006), and researches in dynamic modeling of the robots have been developed by (Mochiyama and Suzuki, 2003; Tatlicioglu et al., 2009).

In the research related to the continuum robots, path planning of the robot is a missing part and so far has not been elaborated by the researchers. This paper studies this issue for an n-segment continuum robot and the approaches are implemented numerically and practically on a two-segment robot. In the following sections, initially the kinematics modeling of a multi-segment continuum robot is presented. Then two different approaches for motion planning are introduced to provide singularity robustness and redundancy resolution for the robot. In the final part of the paper the experiment results gathered from practical implementation of the approaches on a two-segment continuum robot (Fig. 1) are presented.