6th IEEE RAS/EMBS International Conference on
Biomedical Robotics and Biomechatronics (BioRob)
June 26-29, 2016. UTown, Singapore

Design and Prototyping of A Concentric Wire-driven Manipulator

Zheng Li, *IEEE Member*, Chengzhi Song, and Hongmin Wang

Objective - Minimally invasive surgery has been widely embraced due to its multitude benefits, especially less traumatic. The key to its success is the instruments' accessibility and manipulability inside the confined surgical space. This motivates researchers to develop flexible manipulators, which could bend inside the body cavity. Two representative flexible manipulators include the wire-driven manipulator (WDM) and the concentric tube manipulator (CTM) [1-2]. In general, WDMs excel in curvature control but the lengths of their bending sections are fixed. This limits their accessibility and manipulability [3-4]. In this work, we intend to improve these by a new design.

Method - In this work, we present a concentric wire-driven manipulator (CWM). It is composed of two concentric WDMs. Each WDM contains a flexible backbone and a set of four controlling wires. The wires of the outer WDM are controlled by linear actuators independently. This not only allows the control of curvature but also the stiffness of the outer WDM. The wires of the inner WDM is arranged orthogonally, with two antagonistic wires making a pair. Each pair is controlled by a servo motor. At the overlapped section, the stiffness of the outer WDM dominates. Therefore, the outer WDM acts as the active constraint to the inner WDM. Since the inner WDM is highly under-actuated, at the overlapped section, the bending of the inner WDM conforms to that of the outer WDM. As a result, the inner WDM is segmented into two bending sections and each bending section is highly controllable (both the curvature and the length).

Results - A prototype is developed as in Fig. 1 (a). Its diameter is 8 mm, which is the same as that of da Vinci arms. The CWM moves in line with the design idea as shown in figure 1 (c). When the outer WDM is stiffened, the inner WDM could translate along the outer WDM. The overlapped section follows the shape of the outer WDM, while the distal section could bend freely. The CWM could hold payload up to 10 grams as shown in Fig. 1 (b). This indicates it could lift tissues in surgeries.

Conclusion - Compared to the existing flexible manipulator designs, this CWM design could greatly enhances the accessibility and manipulability of the manipulator. It is suitable for designing MIS manipulators.

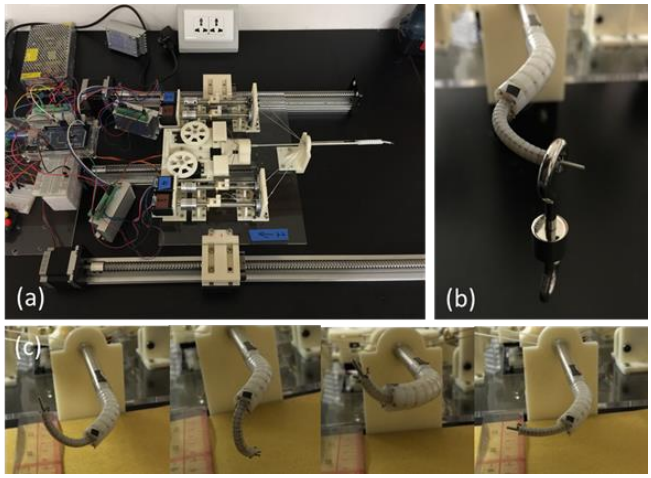

Fig. 1 The Concentric Wire-driven Manipulator (CWM): (a) the CWM prototype; (b) the CWM holding a 10-gram weight; (c) various bending configurations of the CWM.

Research supported by the Shun Hing Institute of Advanced Engineering (SHIAE), the Chinese University of Hong Kong, with project No.8115049 and Innovative Technology Fund (ITF), Hong Kong, with Project No. ITS/019/15.

Zheng Li is with the institute of digestive disease and Chow Yuk Ho Technology Centre for innovative Medicine, the Chinese University of Hong Kong, Hong Kong. (Phone: +852-39434240; Email: lizheng@cuhk.edu.hk)

Chengzhi Song is with the institute of digestive disease, the Chinese University of Hong Kong, Hong Kong. (Email: songchengzhiinhk@gmail.com)

Hongmin Wang is with the institute of digestive disease, the Chinese University of Hong Kong, Hong Kong. (Email: 919427776@139.com)

REFERENCES

[1]. G. Robinson and J. B. C. Davies, "Continuum robots - A state of the art," in IEEE International Conference on Robotics and Automation, Detroit, MI, 1999, pp. 2849-2854.

[2]. R. J. Webster and B. A. Jones, "Design and Kinematic Modeling of Constant Curvature Continuum Robots: A Review," International Journal of Robotics Research, vol. 29, pp. 1661-1683, Nov 2010.

[3]. Z. Li and R. Du, "Expanding Workspace of Underactuated Flexible Manipulator by Actively Deploying Constrains," in IEEE International Conference on Robotics and Automation (ICRA 2014), Hong Kong, China, 2014, pp. 2901-2906.

[4]. Z. Li, H. Ren, P. W. Y. Chiu, R. Du, and H. Yu, "A novel constrained wire-driven flexible mechanism and its kinematic analysis," Mechanism and Machine Theory, vol. 95, pp. 59-75, 2016.