METABot - Magnetic Extensible Tendon Actuated Continuum Robot

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***Abstract*— Continuum manipulators possess the ability to move along nonlinear paths and avoid obstacles in confined environments. However, existing designs have some inherent restrictions: limited range of curvatures or fixed segment lengths. Hence, to achieve motion along a tortuous path in a confined environment in a follow-the-leader manner requires thoughtful a priori design parameter selection. As a result, follow-the-leader motion is only achievable for a limited number of cases. Here, we present a novel miniaturized (7 mm diameter) tendon-driven manipulator design with extensible segments (METABot) enabling follow-the-leader movement.**

Preferred type of presentation: Oral

I. Motivation and Problem Definition

Continuum robots are composed of one (or more) elastic continua leading to increased dexterity and manipulability. Diverse continuum manipulator designs have been proposed thus far [1]. However, these robot designs cannot necessarily deploy along a path in a follow-the-leader motion. This is highly desirable as the majority of applications for continuum robots involve confined and tortuous workspaces.

II. Related work

While concentric tube continuum robots can vary the length of a segment during actuation, the precurvature of each component tube and the elastic interaction between the tubes determines the range of achievable curvatures. On the other hand, tendon-driven manipulators enable a larger variety of curvatures for each segment, but the length of each segment is fixed such that deployment can only be achieved through linear translation of the whole manipulator. Fluidic or pneumatic actuated continuum manipulators allow for limited extension/contraction of the manipulator ($\approx$30 %). For those manipulators, follow-the-leader motion along a specific tortuous path requires a custom choice of segment lengths and curvature ranges. Recently, concurrent developments led to novel continuum manipulator designs with inherent follow-the-leader motion capabilities ([2] and [3]).

III. Own Approach and Contribution

In this paper, we present our recent advancements for our magnetic extensible tendon-driven continuum robot (METABot) design [3]. While we previously presented promising follow-the-leader simulation results [4], we now performed initial experiments on the METABot prototype.

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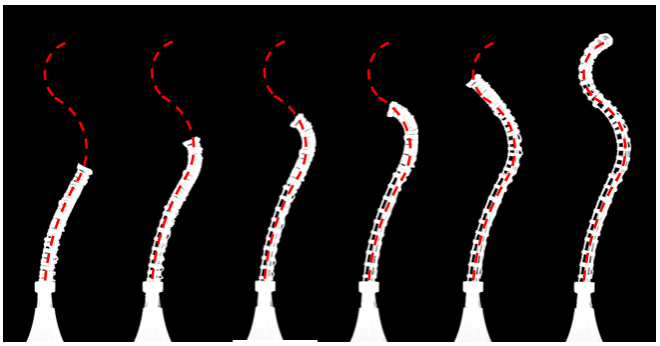

Fig. 1: Follow-the-leader deployment along a desired path (dashed red line).

We adopt our previous design [3] and expand it to 3 segments. Each segment bends and extends/contracts independently resulting in 9 DOF for the whole manipulator. Each segment can vary its length between 15-70 mm.

The spacer disks were further reduced in diameter (now 7 mm) and are equipped with permanent magnets (Neodymium) to ensure equidistant distribution during extension/contraction. The backbone is composed of 3 telescoping, straight, and superelastic NiTi tubes. To achieve independent actuation we use 12 DC motors with encoders (Maxon Motor AG, Switzerland), 9 for tendon actuation and 3 for the segment extension/contraction. The motors are controlled by a motion controller (DCM4040/DCM4080, Galil Motion Control, CA, USA).

In order to evaluate the follow-the-leader behavior qualitatively, we chose a random path with three constant curvature sections and taught in ten intermediate configurations along this path. Fig. 1 shows photographs taken from the motion sequence. We can observe, that the manipulator deploys well along the desired path (dashed red line) with slight deviations on the transition from one curvature to the next. The results are promising and we are currently in the process of conducting quantitative experiments.

References

[1] J. Burgner-Kahrs, D. C. Rucker, and H. Choset, "Continuum Robots for Medical Applications: A Survey," *IEEE Transactions on Robotics*, vol. 31, no. 6, pp. 1261–1280, 2015.

[2] B. Kang, R. Kojcev, and E. Sinibaldi, "The First Interlaced Continuum Robot, Devised to Intrinsically Follow the Leader," *Plos One*, vol. 11, no. 2, 2016.

[3] T.-D. Nguyen and J. Burgner-Kahrs, "A Tendon-Driven Continuum Robot with Extensible Sections," in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2015, pp. 2130–2135.

[4] M. Neumann and J. Burgner-Kahrs, "Considerations for Follow-the-Leader Motion of Extensible Tendon-driven Continuum Robots," in *IEEE International Conference on Robotics and Automation (in press)*, 2016.