Multi-Link Cable Driven Robots with Mechatronic Stiffness

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Abstract

The paper deals with the proposal for efficient multi-link cable driven robots by improvement based on cable based mechatronic stiffness. Multi-link cable driven robots (MLCDR) are recently intensively investigated (e.g. [1]). They are attractive for good potential of stiffness due to serial joint based structure in contrast to tensegrity and due to lightweight actuation. However, they suffer from multiple actuation and structure loading.

This paper proposes a different approach for usage of MLCDR advantages. The straightforward direct approach of planar MLCDR is in Figure 1 [3]. It is based on serial robot. The links are actuated by couples of cables Ci for antagonistic influence. The structure is loaded by these driving forces. This is mitigated by various routing of cables up to the number of cables equal to number of DOFs plus one.

Therefore it is proposed to equip each link by module of mechatronic stiffness Si (Figure 2 and Figure 4). Then MLCDR can be actuated just by cables routed through the central tubus with the same number of drives Di as robot DOFs (Figure 3).

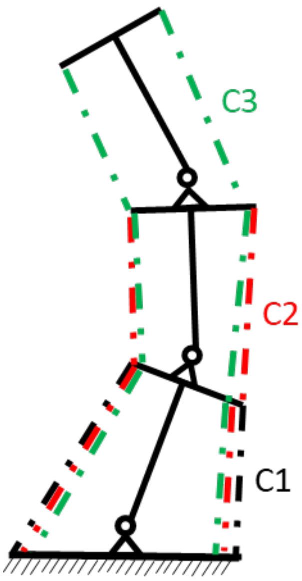

Figure 1 Direct MLCDR

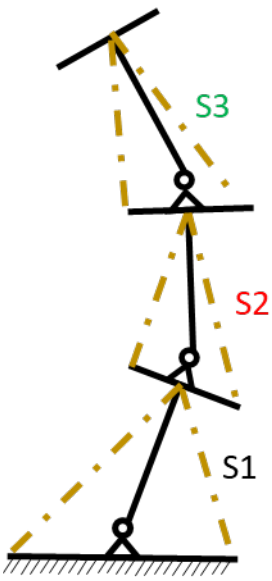

Figure 2 Mechatronic cable stiffness

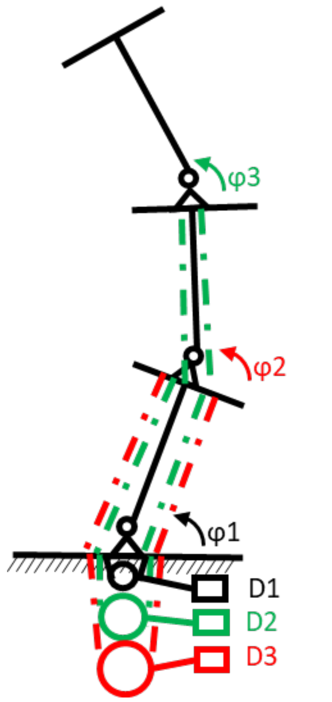

Figure 3 Proposed solution

The mechatronic stiffness is a specific concept for modification of any mechanical construction/structure. It consists of creating a concurrent auxiliery structure to the basic supporting structure, both structures are connected in one or more connecting points by actuators that are controlled based on deformation/motion of this connecting points. Such modification has many positive influences on mechanical properties of modified structure, especially the increase of stiffness. The original concept has been extended to the concept of mechatronic stiffness by cables [4-5].

This concept was applied for machine tools [4-5] with very promising results. It is applied here for each link (Figure 4). The tip of the link is connected by two cables via two pulleys to the preload spring k. This is passive solution, true mechatronic one would be with driven pulleys. Even the passive solution increases the stiffness and damping 10x [5]. The link is actuated by another pulley by force F_{Di}. The advantage is that the antagonistic forces necessary for cable mechanisms [2] are solved by the mechatronic stiffness at each link (Figure 4 initial variant and Figure 5 optimized variant) and the driving cables are routed through the central tubus (Figure 3). The loading forces are equal to torques acting on links as in case of traditional serial robots.

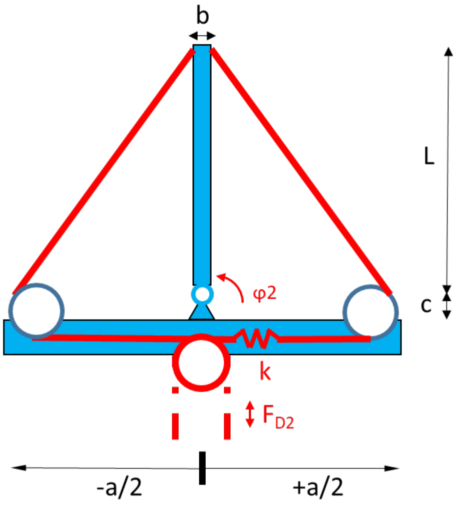

Figure 4: Mechatronic stiffness of one link

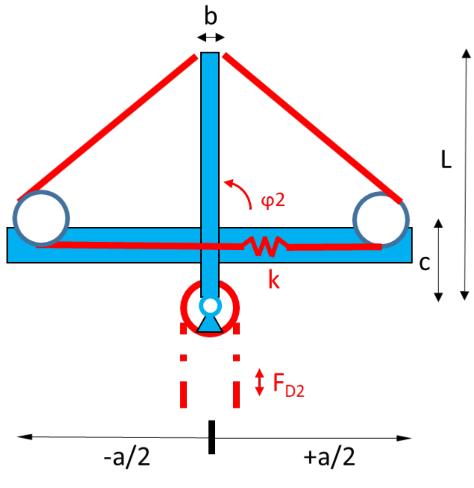

Figure 5: Optimized varia nt

If the robot includes not only revolute joints but spherical joints then a challenge is to transfer these results into space. The basis for that is the set of spatial spherical parallel mechanisms [5] – HexaSphere, EcoSphere, DoubleSphere, QuatroSphere (Figure 5). Their movability is +- 100 degrees and they require to use subsequently 6, 3, 3, 4 drives. If some of these mechanisms can be actuated by cables instead of struts then it can represent a solution for one link of spatial MLCDR. The HexaSphere can be actuated by cables. The answer for other mechanism from Figure 5 is still open.

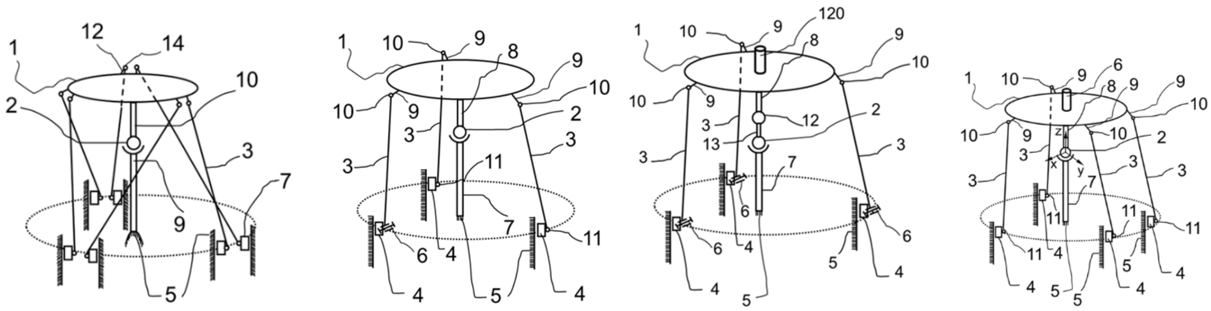

Figure 5: Spatial spherical parallel mechanisms

The number of drives would be the number of links times the number of actuators for mechanisms on Figure 5. The paper investigates the required forces in cables and the resulting stiffness of MLCDRs.

References

[1] Guo, Y., Lao, D.: A Design Method of Multi-link Cable Driven Robots Considering the Rigid Structure Design and Cable Routing, In: Caro, S. et al. (eds.): Cable Driven Parallel Robots, Springer, Cham 2023, pp. 249-260

[2] Pott, A.: Cable-Driven Parallel Robots, Springer 2018

[3] Valasek, M. et al.: Manipulator, EP 2762280A1

[4] Valasek, M. et al.: A device for changing the dynamic stiffness of a gantry or overhung structure, PCT/CZ2020/0000

[5] Neusser, Z. et al.: Mechatronic stiffness of cable-driven mechanisms: a study on production machine model, The International Journal of Advanced Manufacturing Technology, 123, pages431–446 (2022)

[6] Valasek, M. Storkan, J.: Dexterity Improvement of Pointing Spherical Mechanism by Trajectory Planning, In: Proc. of The 4th Joint International Conference on Multibody System Dynamics, Montreal 2016, pp. 1-7