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Eigenmotion concept of cable driven mechanism with absorbing elements

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The paper deals with the principle of eigenmotion, which is based on the idea of keeping the total energy constant during the motion of the mechanism. The idea of applying the eigenmotion principle is mainly linked to single-purpose mechanisms where there is a requirement to move along a periodically repeating trajectory [2]. Therefore, the paper deals with the extension of the eigenmotion principle to cable-driven mechanisms which potentially has a larger number of members giving the possibility of generating more complex trajectories or easier reconfiguration of the manipulator for switching from one eigenmotion trajectory to another.

The concept of eigenmotion is examined on two basic cable-driven manipulators. The first one is an inverse pendulum controlled by two cables (Fig. 1) and the second one is a body in planar space controlled by four cables (Fig. 2). Both concepts have two types of additional springs – the soft springs which directly connect the moving body and frame and the tension springs which prestress the cables and keep the level of prestress at certain level.

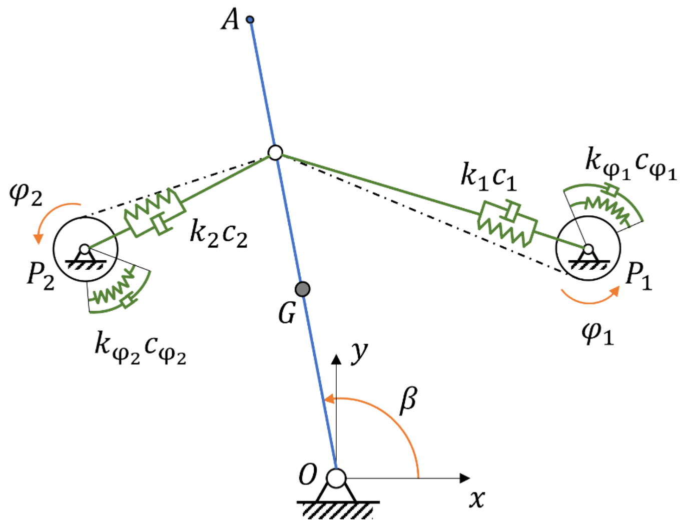

Fig. 1. A scheme of the inverse pendulum cable-driven manipulator designed for eigenmotion: k_{1-2} – soft springs with damping c_{1-2}, $k_{\varphi_{1-2}}$ – tension torsional springs with damping $c_{\varphi_{1-2}}$, G – centre of gravity, A – end-effector, O – rotational joint

The eigenmotion trajectory generation is based on the undamped scheme of the dynamic model, where repetitive point-to-point trajectories are considered. The dynamic model is assembled considering non-rigid cable model with variable stiffness depended on the actual cable length $k_{cable}(l_{cable})$. The i-th pulley is modelled as

$$I_{1Pi}\ddot{\varphi}_i = M_{c_i} - S_{cable_i} r_{Pi} - M_{k_{\varphi_i}} - M_{c_{\varphi_i}}, \tag{1}$$

where I_{1Pi} is the moment of inertia, M_{c_i} is moment generated by the motor, r_{Pi} is the radius of the pulley, S_{cable_i} is the force in the i-th cable, $M_{k_{\varphi_i}} = k_{\varphi_i}(\varphi_i - \varphi_{0_i})$ is the moment generated by the torsional spring and $M_{c_{\varphi_i}} = c_{\varphi_i}(\dot{\varphi}_i - \dot{\varphi}_{0_i})$ is the damping moment.

The control scheme is based on the computed torque method (CTM), which uses the inverse dynamics, and the cable force distribution, which defines the input M_{c_i}, is solved by the singular value decomposition (SVD) [1]. The final values of the control input M_{c_i} are optimized so that the control inputs M_{c_i} are minimized. This approach leads to the minimum energy costs, which are needed to stay on the eigenmotion trajectory and overcome the damping, model imperfections (parameters in the regulator are chosen a little differently than in the dynamic model), disturbances etc.

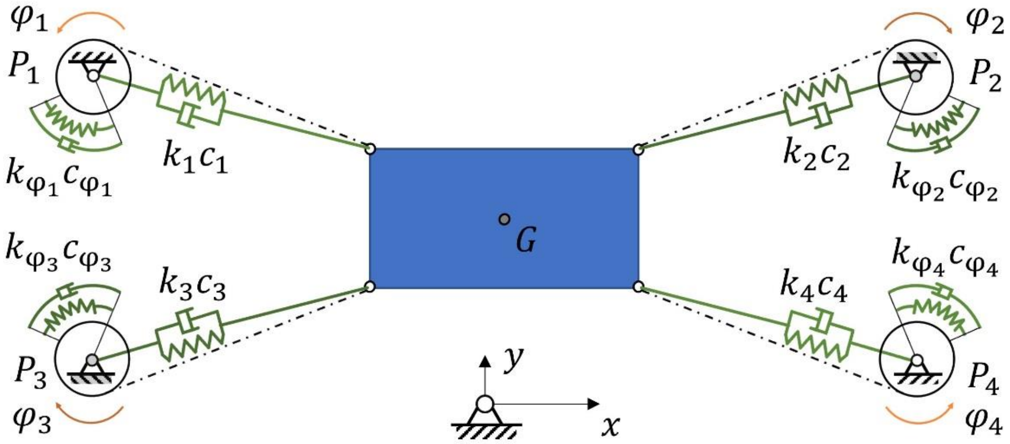

Fig. 2. A scheme of the body in planar space designed for eigenmotion: k_{1-4} – soft springs with damping c_{1-4}, $k_{\varphi_{1-4}}$ – tension torsional springs with damping $c_{\varphi_{1-4}}$, G – centre of gravity

In conclusion, the brief investigation to the eigenmotion idea of cable driven mechanism with absorbing elements is shown. Two planar models are presented and described. The control algorithm uses CTM with control inputs M_{c_i} using SVD with optimization algorithm which keeps the input moments at minimum level as close as possible to the passive prestress in cables during the eigenmotion motion. The simulation results show that the control algorithm keeps the motion of the mechanism on the chosen eigenmotion trajectory.

The future work considers the extension to more complex structures and mechanisms where additional soft springs can be rearranged so that the eigenmotion trajectory can be more complex and reconfigurable.

Acknowledgements

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