Mobile Cable-Driven Parallel Robots

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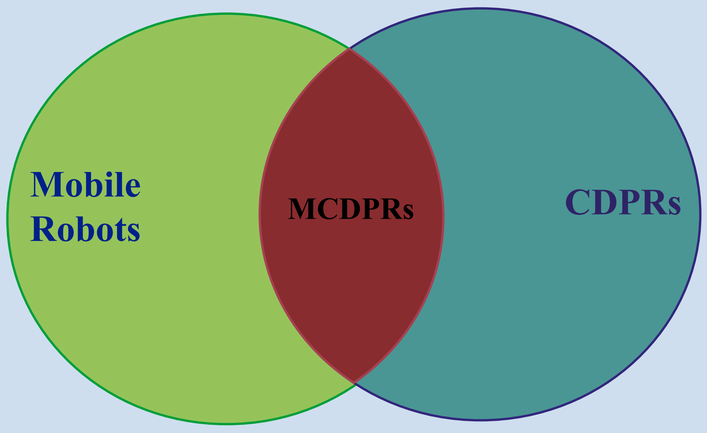
Introduction

In the last 5 years, automated technical solutions for picking have emerged in the areas of production or logistics. These solutions are based on the coupling of robotic arms, Cable-Driven Parallel Robots (CDPRs) and AGVs, however manufacturers have not yet succeeded in developing robust and versatile products. In this context, Mobile Cable-Driven Parallel Robots (MCDPRs) presents a new technical innovation that could help to bring more flexibility and versatility with respect to existing solutions.

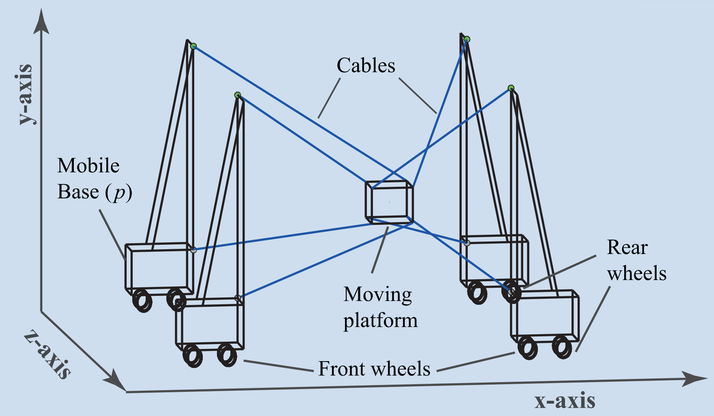
MCDPRs

MCDPRs contains partial mobility of CDPRs and partial mobility of Mobile Robots.



Mobility of MCDPRs

Spatial MCDPR



MCDPR with $p = 4$, $q = 8$ and $n = 6$

Feasible Cable Tension Domain (FCTD) for a planar MCDPR

A MCDPR is composed of a CDPR with q cables and a n degree-of-freedom moving-platform mounted on p mobile bases. A planar MCDPR composed of four cables and two mobile bases is illustrated in Fig. 1. Contrary to classical CDPRs, the additional constraints associated with the equilibrium of the MCDPR Mobile bases must be taken into account while calculating the tension in the cables. These contraints are defined as the moments generated by the externnal forces at point C_{rj} (C_{lj}, resp.) should be counterclockwise (clockwise, resp.), namely,

$$m_{rj} \geq 0, \quad m_{lj} \leq 0, \quad j = 1, 2$$

The equilibrium consraints are mapped in the tension space [1] can be written along with the cable tension limlit consraints as:

$$\begin{bmatrix} \underline{\mathbf{t}} - \mathbf{t}_p \\ \underline{\mathbf{m}} \end{bmatrix} \leq \begin{bmatrix} \mathbf{N} \\ \mathbf{N_c} \end{bmatrix} \boldsymbol{\lambda} \leq \begin{bmatrix} \overline{\mathbf{t}} - \mathbf{t}_p \\ \overline{\mathbf{m}} \end{bmatrix}$$

where:

$$\mathbf{N_c} = \begin{bmatrix} \mathbf{n}_{Cl1} \\ \mathbf{n}_{Cr1} \\ \mathbf{n}_{Cr2} \\ \mathbf{n}_{Cl2} \end{bmatrix}, \ \underline{\mathbf{m}} = \begin{bmatrix} \underline{m}_{Cl1} \\ -\infty \\ -\infty \\ \underline{m}_{Cl2} \end{bmatrix}, \ \overline{\mathbf{m}} = \begin{bmatrix} \infty \\ \overline{m}_{Cr1} \\ \overline{m}_{Cr2} \\ \infty \end{bmatrix}$$

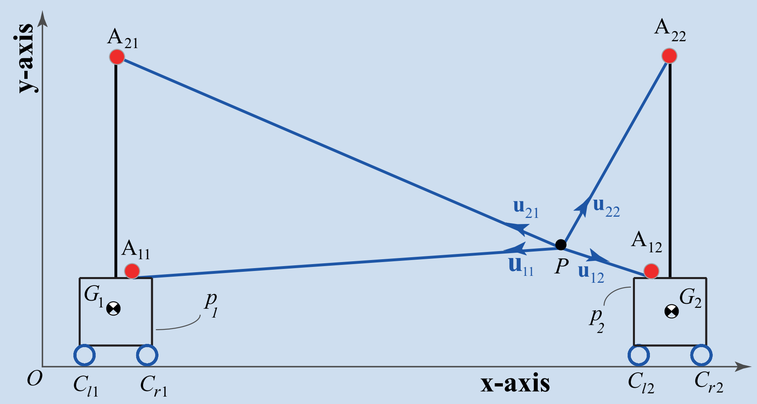
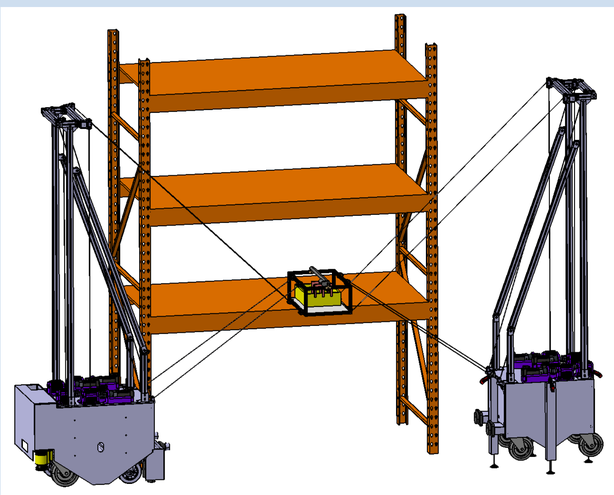


Fig. 1: Planar MCDPR

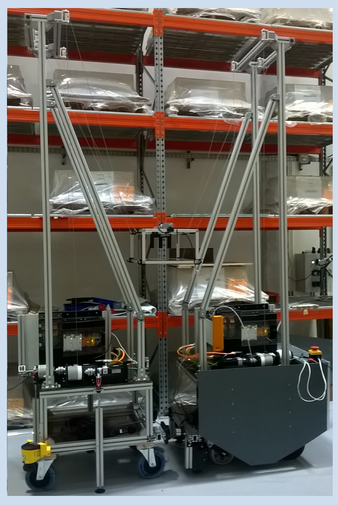
Where $t_p = [t_{p11}\ t_{p21}\ t_{p12}\ t_{p22}]^T$ is a particular solution (Minimum Norm Solution) for the tension in the cables. $\boldsymbol{\lambda} = [\lambda_1\ \lambda_2]$ is a two dimensional arbitrary vector that moves the particular solution into the feasible range of cable tensions. $\overline{m}_{Crj}$ ($\underline{m}_{Clj}$, resp.) is the moment generated by the weight of the jth mobile base and the forces in the cables due to t_p at point C_{rj} (C_{lj}, resp.). $\underline{\mathbf{t}}$ and $\overline{\mathbf{t}}$ denote the minimum and maximun cable tension limits. $\mathbf{N}$ ($\mathbf{N_c}$, resp.) denote the null space of the cable unit vectors (moment generated by the cable unit vectors, resp.) [1]. FCDT between a CDPR and a MCDPR is compared in Figs. 2 and 3 for the configuration in Fig. 1.

FASTKIT Prototype

FASTKIT prototype is composed of eight cables, a six degree-of-freedom moving-platform and two Mobile Bases. FASTKIT addresses an industrial need for flexible pick-and-place operations while being easy to install, keeping existing infrastructures and covering large areas. The objective is to design and implement a system capable of interacting with a high level task planner for logistic operations. Thus the system must be capable of autonomously navigating to the task location, deploying the system such that the task is within the reachable workspace and executing a pick-and-place task.



FASTKIT Catia Model



Undeployed

Deployed

Feasible Polygons

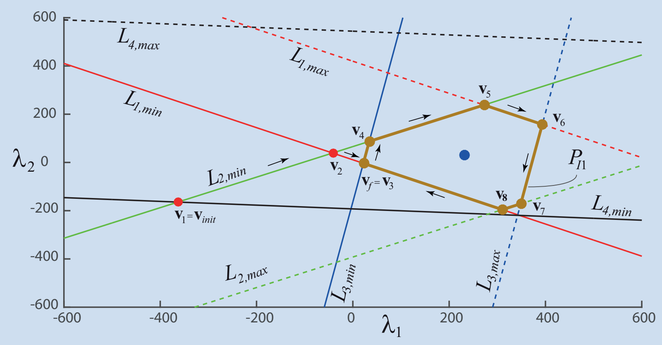


Fig. 2: Feasible Polygon P_{I1} considering only tension limit constraints

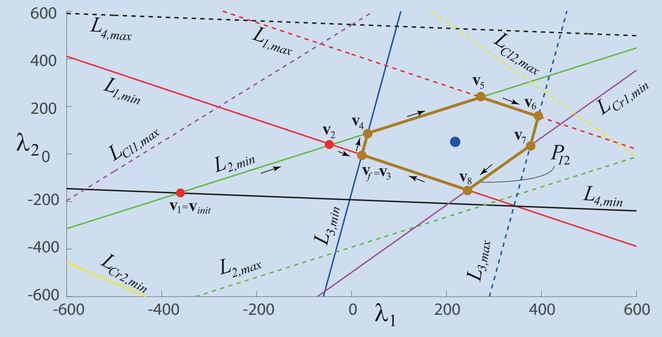


Fig. 3: Feasible Polygon P_{I2} considering both tension limit and equilibrium constraints

Conclusion

One of the biggest challenges in classical CDPRs which have a fixed cable layout, *i.e.* fixed exit points and cable configuration, is the potential collisions between the cables and the surrounding environment that can significantly reduce the workspace of the robot. On the contrary, Mobile Cable-Driven Parallel Robots are more flexible and versatile, capable of modifying the CDPR architecture based on the task feasibility. The objective of this thesis is to study different types of Mobile Cable-Driven Parallel Robots using different combinations of Mobile Robots with Cable-Driven Parallel Robots.

References

[1] Rasheed, T., Long, P., Marquez-Gamez, D. and Caro, S., "Tension Distribution Algorithm for Planar Mobile Cable-Driven Parallel Robots", *The Third International Conference on Cable-Driven Parallel Robots (CableCon 2017)*, Quebec City, Canada, August 2-4 2017.