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## A CLASS OF PLANAR 3-DOF CABLE-DRIVEN PARALLEL ROBOTS WITH DECOUPLED WORKSPACE

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### 1 INTRODUCTION

Cable-Driven Parallel Robots (CDPRs) consist of a base frame and a moving-platform (MP) connected by cables. The movement of the MP is achieved by varying the cable lengths. Planar 3-degree-of-freedom (3-dof) CDPRs can have a large translational workspace [1] but their MP rotation is highly coupled with its position and generally limited. A solution has been proposed in [2] to increase the workspace by adding an X-joint to the MP. This paper proposes a class of planar 3-dof CDPRs that feature a large wrench-feasible workspace (WFW) where the set of reachable positions is the same for any orientation of the MP. The proposed CDPR features a circular MP and the cables can wind around it, similar to the haptic device proposed in [3].

### 2 DESCRIPTION OF THE PROPOSED CDPR

The proposed planar CDPR consists of 4 cables and a circular MP. Unlike existing planar CDPRs, the cables are not attached to the MP, but can wind around it as shown in Fig. 1. For a given position of the MP, the cable directions remain constant for any orientation of the MP. Therefore, the effect of the cable tensions exerted on the MP does not depend on the MP orientation.

### 3 COMPARISON WITH A CLASSICAL CDPR

We compare the wrench-feasible workspace (WFW) of the proposed CDPR to a CDPR with a square MP. A tool is attached to the MP to distinguish between the different MP orientations  $\phi$ . The reference point is the geometric center of the MP. The static equilibrium equation of the MP can be written in a matrix form as:

$$\mathbf{W}\mathbf{t} + \mathbf{w}_e = \mathbf{0}_3 \quad (1)$$

where  $\mathbf{0}_3$  is the 3-dimensional zero vector,  $\mathbf{w}_e$  is the external wrench,  $\mathbf{t}$  is the cable tension vector and  $\mathbf{W}$  is the wrench matrix. The WFW is calculated by scanning the Cartesian space for 5 different MP orientations:  $\phi = 0, \pi/4, \pi/2, 3\pi/4$  and  $\pi$  rad. For each MP pose, we verify the static equilibrium equation (1), where the external wrench  $\mathbf{w}_e$  is considered as the gravity wrench  $\mathbf{w}_g$ . We scan one of the 4 cable forces and solve (1) for the other 3 forces. The tested pose belongs to the WFW if a set of 4 forces  $f_i$  is found between the cable tension lower bound  $f_{min}$  and the cable tension upper bound  $f_{max}$  with  $f_{min} = 0$  and  $f_{max} = 120$  N. The side of the square MP and the diameter of the circular MP are 1.2 m. The mass of each MP and tool is 1 kg. Figure 2 shows the WFW of the CDPRs with a square MP for the 5 MP orientations tested, along with the WFW of the CDPR with a disc MP (which is identical for each MP orientation). Clearly, the WFW of the CDPR with a square MP is reduced when its orientation  $\phi$  is not null. When  $\phi = \pi$ , the WFW touches the left and right sides of the CDPR frame, but does not reach its top.

We have also compared the two CDPRs when the MP needs to apply a force along the x, y and -x axes, such as in drilling tasks. For a finer comparison analysis, we have used the capacity margin (CP), which indicates how far the cable tensions are from their lower and upper limits in the WFW. The results (not shown here for lack of space) show that the CDPR with a circular MP behaves much better than the MP with a square MP: the CP of the former is much greater within its WFW and the latter has one of its cables almost slack in most of its WFW.

### REFERENCES

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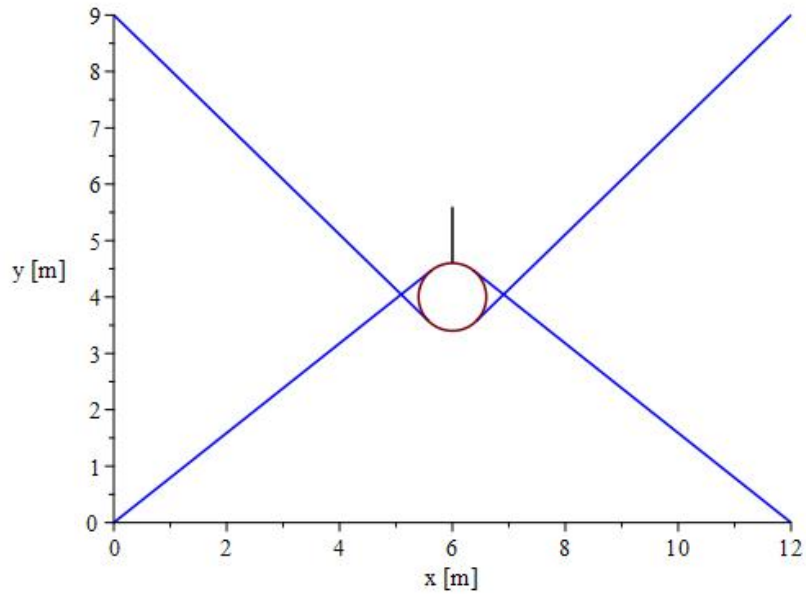


Figure 1: The proposed 3-dof planar CDPR.

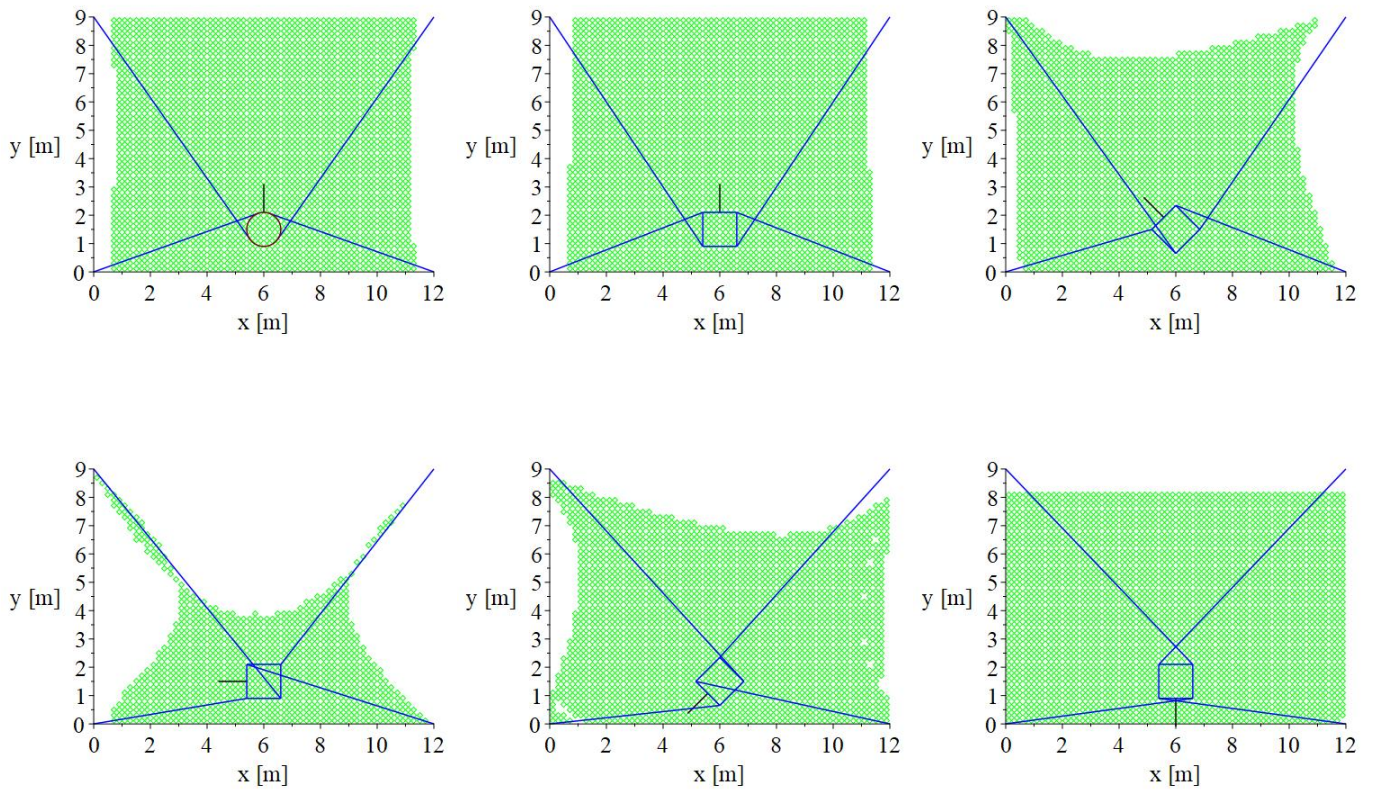


Figure 2: Upper left plot: WFR of the CDPR with a circular MP, which is identical for each MP orientation. Following plots: WFR for the CDPR with a square MP when  $\phi = 0, \pi/4, \pi/2, 3\pi/4$  and  $\pi$  rad.