ROPAH–Parallel Robots

Lecture – Project   **January 27, 2020**

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1 Introduction

The ROPAH practical work is evaluated with a final project that is conducted by groups of two students. Projects are suggested by the instructor. A final report is due at the end of the practical work. Three project subjects are described thereafter.

Each group of two students should choose one the three projects. For each project,

1. The design problem should be formulated as an optimization problem based on the given specifications;

2. A list of manipulators should be synthesized by using the screw theory and virtual-chain approach;

3. The proposed manipulator architectures should be evaluated based on their complexity;

4. A good candidate amongst the obtained manipulator architectures should be selected for detailed design and CAD modeling with CATIA software;

5. A animation of the final design should be made;

2 Project 1: Design of a three degrees of freedom planar parallel manipulator

The subject of Project 1 is about the design of a three degrees of freedom planar parallel manipulator. Here are the specifications:

1. The manipulator should have a cylindrical regular workspace of diameter equal to 100 mm, its height corresponding to the range of rotation of the moving-platform.

2. The range of rotation of the moving platform should be higher than 60° throughout the regular workspace.

3. The inverse condition numbers of its normalized forward and inverse Jacobian matrices should be larger than 0.1 throughout the regular workspace.

4. The manipulator should be compact, i.e., the overall size of the manipulator should be as small as possible.

5. For a force equal to 10 N applied on the moving-platform along the normal to the plane of motion in its home configuration, the point-displacement of the moving-platform should be lower than 0.1 mm.

You are referred to papers [1, 2, 3] to have some information on the determination of the normalized forward and inverse Jacobian matrices of a planar parallel manipulator and the formulation of a robot design optimization problem.

3 Project 2: Design of a three degrees of freedom translational parallel manipulator

The subject of Project 2 is about the design of a three degrees of freedom translational parallel manipulator. Here are the specifications:

1. The manipulator should have a cubic regular workspace of size 500 mm × 500 mm × 500 mm.

2. The inverse condition number of the normalize kinematic Jacobian matrix should be larger than 0.1 throughout the regular workspace.

3. The manipulator should be compact, i.e., the overall size of the manipulator should be as small as possible.

4. For any force of magnitude 10 N applied on the moving-platform in the plane of motion, the point-displacement of the moving-platform should be lower than 0.1 mm throughout the regular workspace.

4 Project 3: Design of a parallel Schönflies motion generator

The subject of Project 3 is about the design of a parallel Schönflies Motion Generator (SMG). The parallel Schönflies motion generator should be designed for pick-and-place operations based on the path defined to test the performance of SCARA robots, as depicted in Fig. 1. Moreover, one of the objectives of the project is to realize a parallel system that outperforms
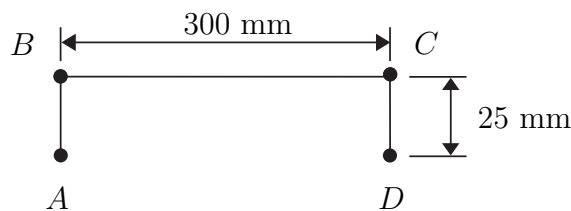

Figure 1: Path adopted for the manipulator design

both serial SCARA systems and the parallel robots currently available for Schönflies motion

generation, i.e., the McGill SMG [4], the H4 [7], the T3-R1 [6], and the fully isotropic parallel mechanisms developed by [5]. To this end, the design specifications for the good under design are given below:

- The robot must be capable of producing a test cycle that is commonly accepted for SCARA systems, in at most 500 ms. The test cycle consists of:

  - 25-mm vertical displacement up
  - 300-mm horizontal displacement with a concomitant 90° turn
  - 25-mm vertical displacement down
  - 25-mm vertical displacement up
  - 300-mm horizontal displacement with a reversed 90° turn
  - 25-mm vertical displacement down

- The system should be capable of attaining a configuration where kinetostatic robustness is achieved. As a matter of fact, from kinetostatics, the SMG is maximally accurate and robust when its normalized forward and inverse Jacobians are maximally invertible, i.e., when their *condition number* κ is as small as possible, i.e., $\kappa < 10$.

- The mechanism should not be too bulky.

The dimensions of the SMG are mainly determined by the isotropy conditions derived in the kinetostatic design, the geometric considerations, and the moveability of the end-effector to achieve the 180° rotation of the test cycle.

References

[1] Caro, S., Chablat, D., Wenger, P., and Angeles, J., The Isoconditioning Loci of Planar Three-Dof Parallel Manipulators, In: G. Gogu, D. Coutellier, P. Chedmail and P. Ray (Editors), Recent Advances in Integrated Design and Manufacturing in Mechanical Engineering, Kluwer Academic Publisher, 2003, ISBN 1-4020-1163-6, pp.129-138. hal-00463599

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[3] Caro, S., Chablat, D., Ur-Rehman, R., and Wenger, P., "*Multiobjective Design Optimization of 3-PRR Planar Parallel Manipulators*", CIRP Design 2010 proceedings book, pp. 373-383.

[4] Angeles, J., Caro, S., Khan, W. and Morozov, A., 2006, The Design and Prototyping of an Innovative Schönflies Motion Generator. Part C, Journal of Mechanical Engineering Science, special issue: Kinematics, Kinematic Geometry and their applications, Vol. 220, N° C7, pp. 935–944, July 2006, hal-00463717.

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[8] Zhu, Y. (2004). The kinetostatic design of a novel parallel schönflies-motion generator. Master's thesis, Department of Mechanical Engineering & Centre for Intelligent Machines, McGill University.