Vienna School of Mathematics

PhD Colloquium

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Singularity Distance Computation for Parallel Manipulators of Stewart-Gough Type

Under the term parallel manipulators of the Stewart-Gough type, we summarize mechanisms, where the moving platform is connected to the base by a certain number of prismatic (P) legs according to the robots degree of freedom (dof). For planar devices, the legs are anchored by passive revolute (R) joints, and for spatial ones by passive spherical (S) joints.

In so-called *singular* (also known as *shaky*) *configurations* these manipulators gain at least one instantaneous DoF. Therefore, minor variations in the manipulator geometry (e.g. backlash in passive joints or uncertainties in the actuation of the P joints) can significantly affect the realized configuration. Another phenomenon that also appears close to these configurations is that the prismatic actuator forces can become very large, resulting in a breakdown of the manipulator. Therefore, singular configurations and their vicinity should be avoided. In this context we consider 3-RPR manipulators and present a comparison of singular distances with respect to extrinsic [1] and intrinsic [2] metrics along a 1-parametric motion. Note that different metrics can be used depending on the chosen interpretations of the platform/base; e.g. as triangular plate or as pin-jointed triangular bar structure.

There also exist so-called *architecture singularities* referring to robot designs, which are shaky in every configuration. Clearly, these designs have to be avoided but also their vicinity, as every anchor point can be associated with a space of uncertainties (e.g. tolerances in the passive joints or deviations of the platform/base from the geometric model). In this context we consider linear pentapods (5-SPS manipulators with linear platform) and present an approach to measure the distance of a given design from being architectural singular.

For both kinds of singularities the distances are computed as the global minima of constrained optimization problems. Their critical points are found through a generic computational pipeline that relies on algorithms from symbolic and numerical algebraic geometry implemented in `Maple`, `Bertini` [3] and `Paramotopy` [4]. Note that we do not only obtain the singularity distance but also the corresponding closest singular configuration and architecture singularity, respectively. All presented approaches are demonstrated on the basis of illustrative examples.

11 December 2023, 16.00-16.45, Vortragsraum Bibliothek TU Wien

(Resselgasse 4, 5th floor)

References:

[1] G. Nawratil, "Singularity Distance for Parallel Manipulators of Stewart Gough Type", Proc. of the 15th IFToMM World Contress on Mechanism and Machine Science, pp. 259-268, 2019.
[2] G. Nawratil, “Snappability and singularity-distance of pin-jointed body-bar frameworks", Mechanism and Machine Theory, vol. (167), pp. 104510, 2022.
[3] D.J. Bates, A.J. Sommese, J.D. Hauenstein, C.W. Wampler, “Numerically solving polynomial systems with Bertini", SIAM, 2013
[4] D.J. Bates, D.A. Brake, M.E. Niemerg, “Paramotopy: Parameter homotopies in parallel", 2018 International Congress on Mathematical Software, pp. 28-35, 2018