Kinematics and trajectories for MIRADAS arms

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Motivation

A detailed probe arm study is required before designing a *collision-free* planning algorithm.

Introduction

The Mid-resolution InfRAreD Astronomical Spectrograph (MIRADAS) is a near-infrared multi-object spectrograph for the Gran Telescopio Canarias (GTC).

- It can simoultaneously select up to *20* targets using *20* deployable cryogenic robotic arms with pickoff mirror optics.
- The bases of the arms are fixed to the same side of a circular platform (MXS plate) and arranged in a circle around the focal plane.
- There is minimum separation between mechanical elements in the MXS Plate.

The instrument was selected in 2010 by GTC and sucessfully passed PDR in November 2012.

Probe arm description

It is a 2 degree-of-freedom (DoF) mechanism that produces a planar motion over the plane formed by the MXS plate.

The mechanism, seen in fig.1 and 2, consists of:

- Two tubes (L_1 and L_3) and a bar (L_2).
- Four joints:
  - J_1, J_2 and J_3 are revolute joints.
  - J_4 rotates about a shaft perpendicular to the view in fig.1 and slides over L_3.

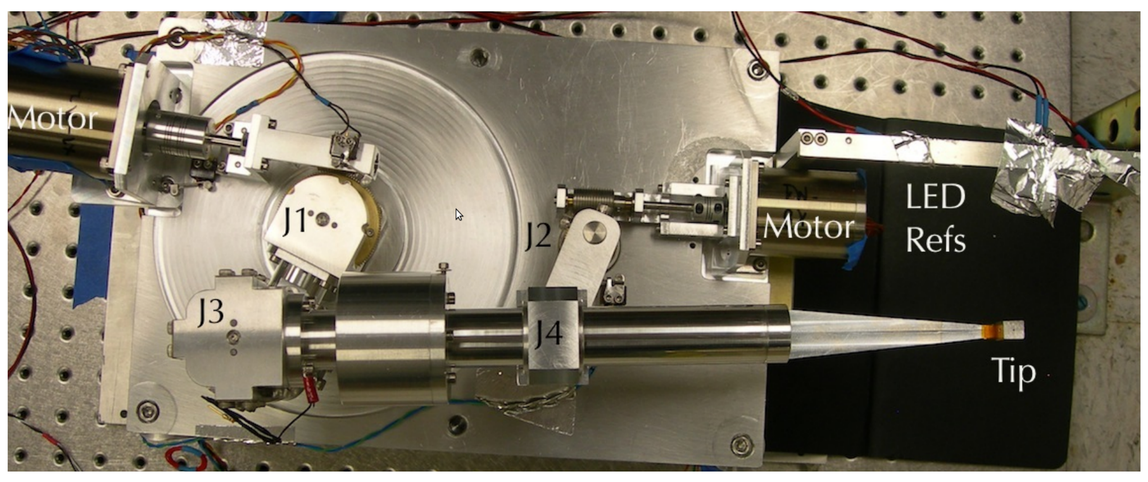


Figure 1: The full-scale MXS probe prototype *P2a* shown from an aerial view.

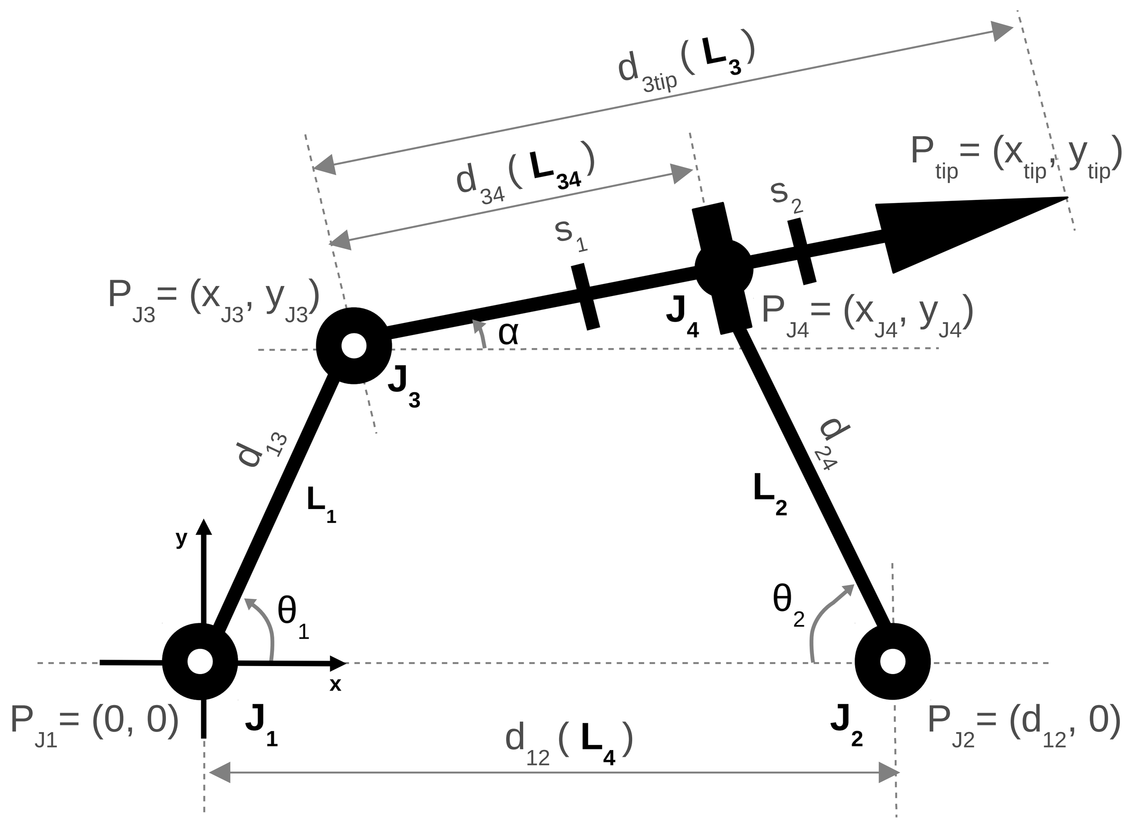
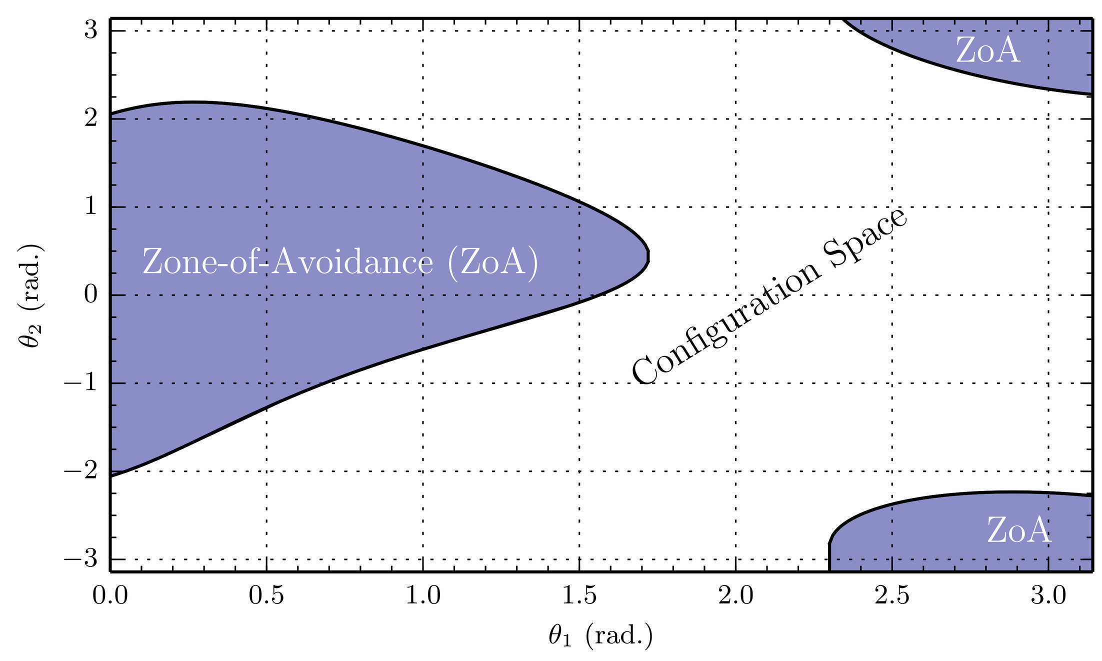


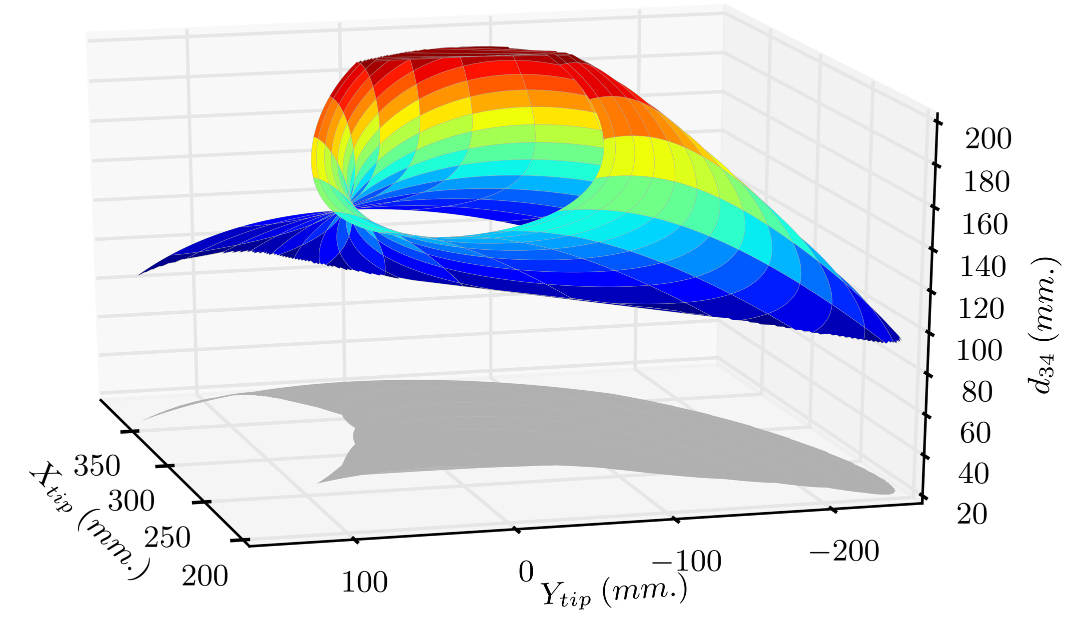
Figure 2: The arm model is a close-loop kinematic chain. Joint J_4 must be always between stop positions s_1 and s_2. The 2 DoF of the mechanism are represented by θ_1 and θ_2, where $\theta_1 \in [0, \pi]$ and $\theta_2 \in [0, 2\pi]$.

Probe arm behaviour

Only a reduced set of (θ_1, θ_2) pairs satisfy the arm mechanical constraints. Each of these pairs forms the arm *configuration space*.



Some tip positions can be reached by two configurations (different J_4 pos.) as can be appreciated in the *3D workspace*.



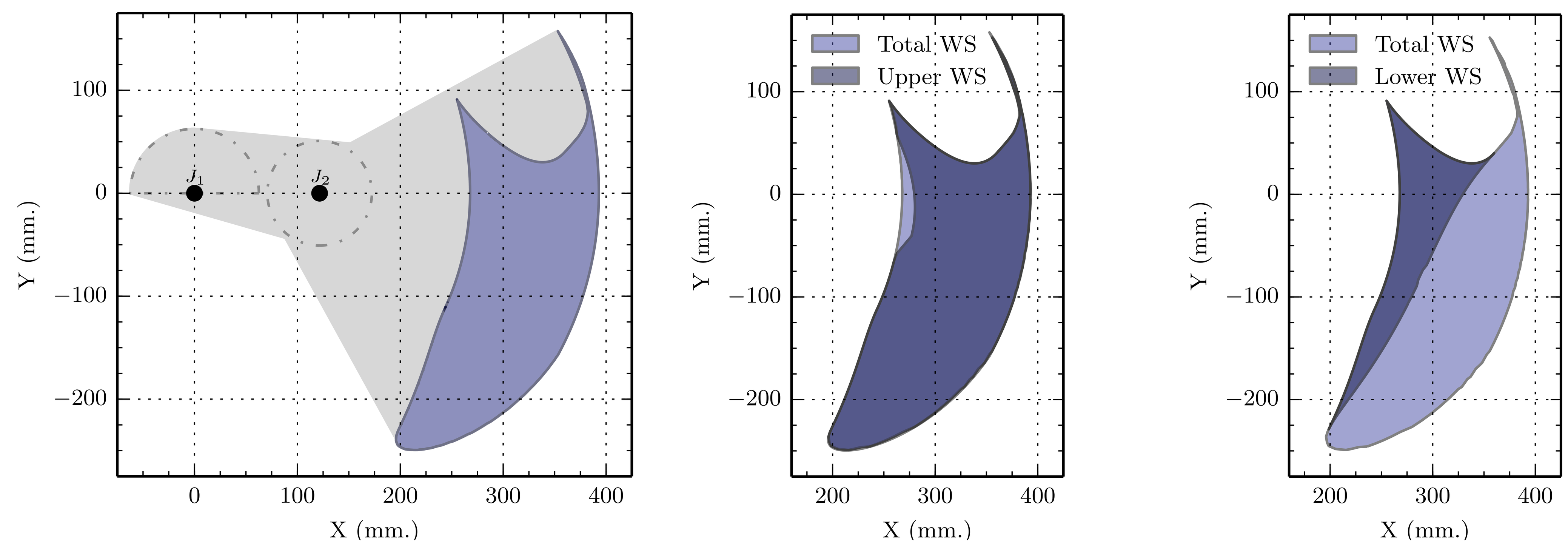


Figure 3: (Left) The arm *envelope* in gray and the *2D workspace* in purple. The *upper* (center) and *lower workspaces* (right) are the projections of the upper and lower sides of the 3D workspace onto the (X,Y) plane.

Patrolling strategies

- ***Workspace***: Each arm patrols the points of its workspace that are in the instrument field-of-view (FoV); see fig.5.
- ***Slice-of-Pie* (SoP)**: FoV is divided into 20 identical areas or SoPs. Each SoP is a subset of the arm workspace. A given SoP is patrolled by only one arm and each arm patrols always the same SoP.

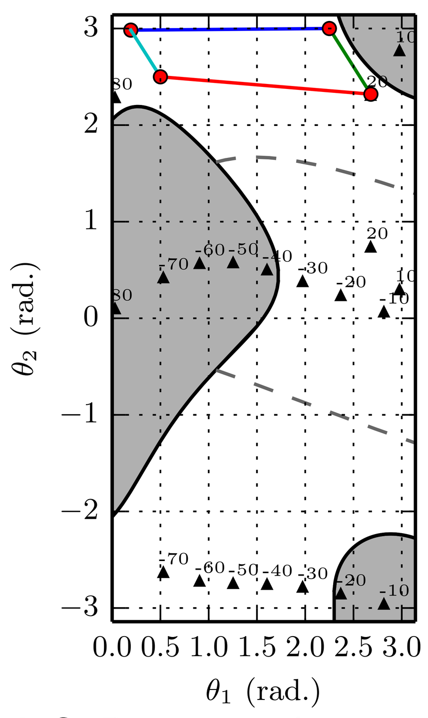
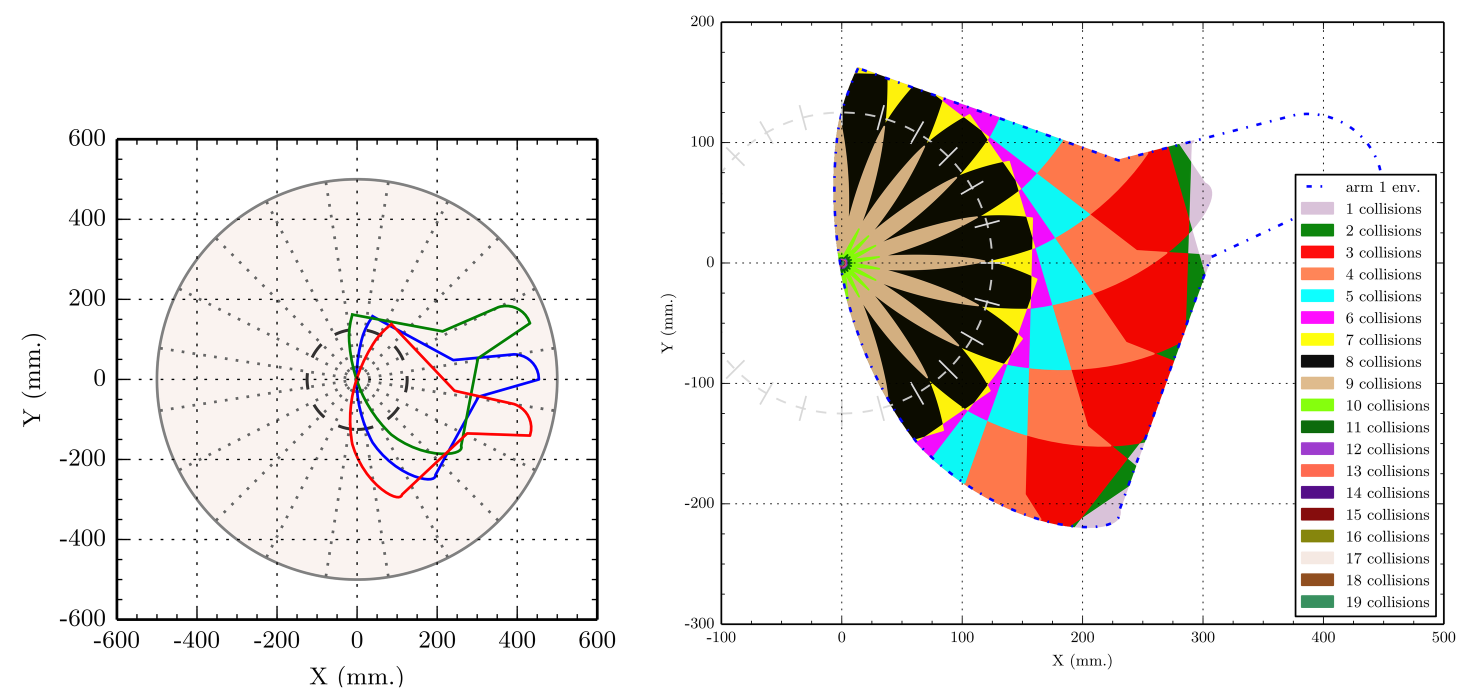


Figure 4: A SoP in articular space that satisfies motor controller constraints.

Figure 5: (Left) envelopes for arm_0 in blue, arm_1 in green and arm_{19} in red; (right) each colored area of the arm_1 envelope specifies the max. number of collisions it can experiment when passing through that zone.



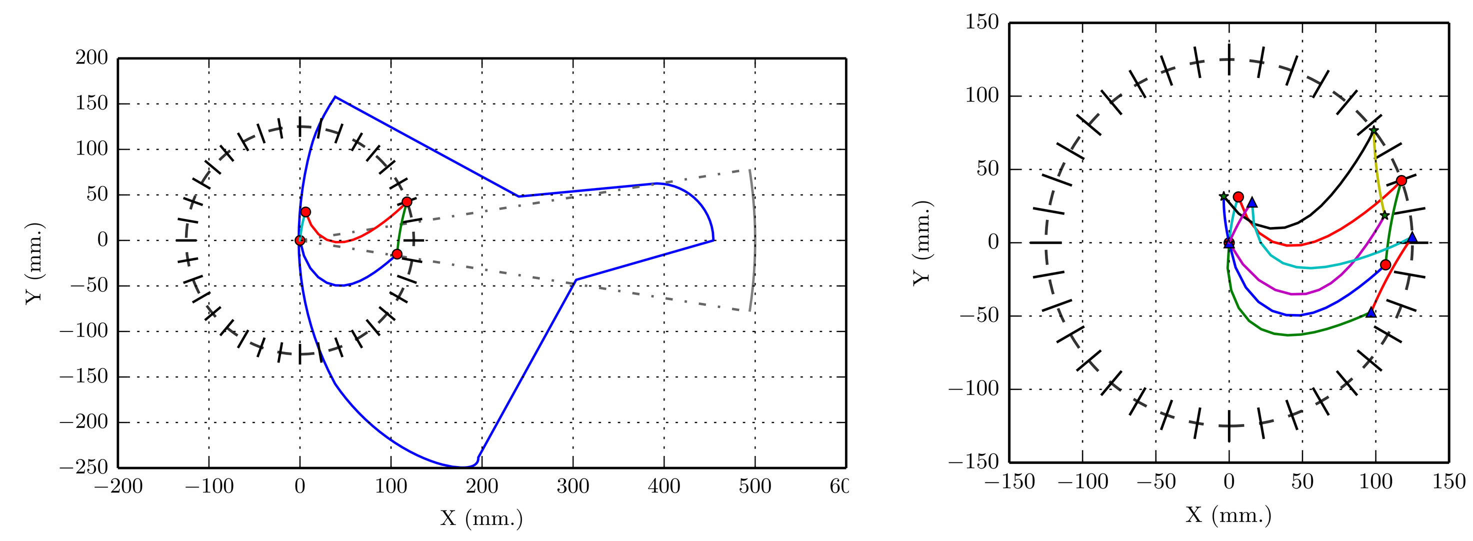


Figure 6: (Left) Cartesian SoP for arm_0 corresponding to the articular SoP in fig. 4; (right) superposition of 3 adjacent SoPs.

Conclusion

1. The arm can work with only configurations belonging to the *upper workspace*, as their patrol almost the total area of the 2D workspace.
2. The workspace patrolling is the approach that enables future planning algorithm to obtain better solutions; however, it can require the use of heuristics for fast convergence to an optimal solution.
3. The options for a proper SoP are drastically reduced, since the restrictions in trajectories imposed by the motor controllers of the prototype. Although this strategy is still usable, it does not ensure that all points of the FoV can be observed.