Planning Shorter Paths in Graphs of Convex Sets by Undistorting Parametrized Configuration Spaces

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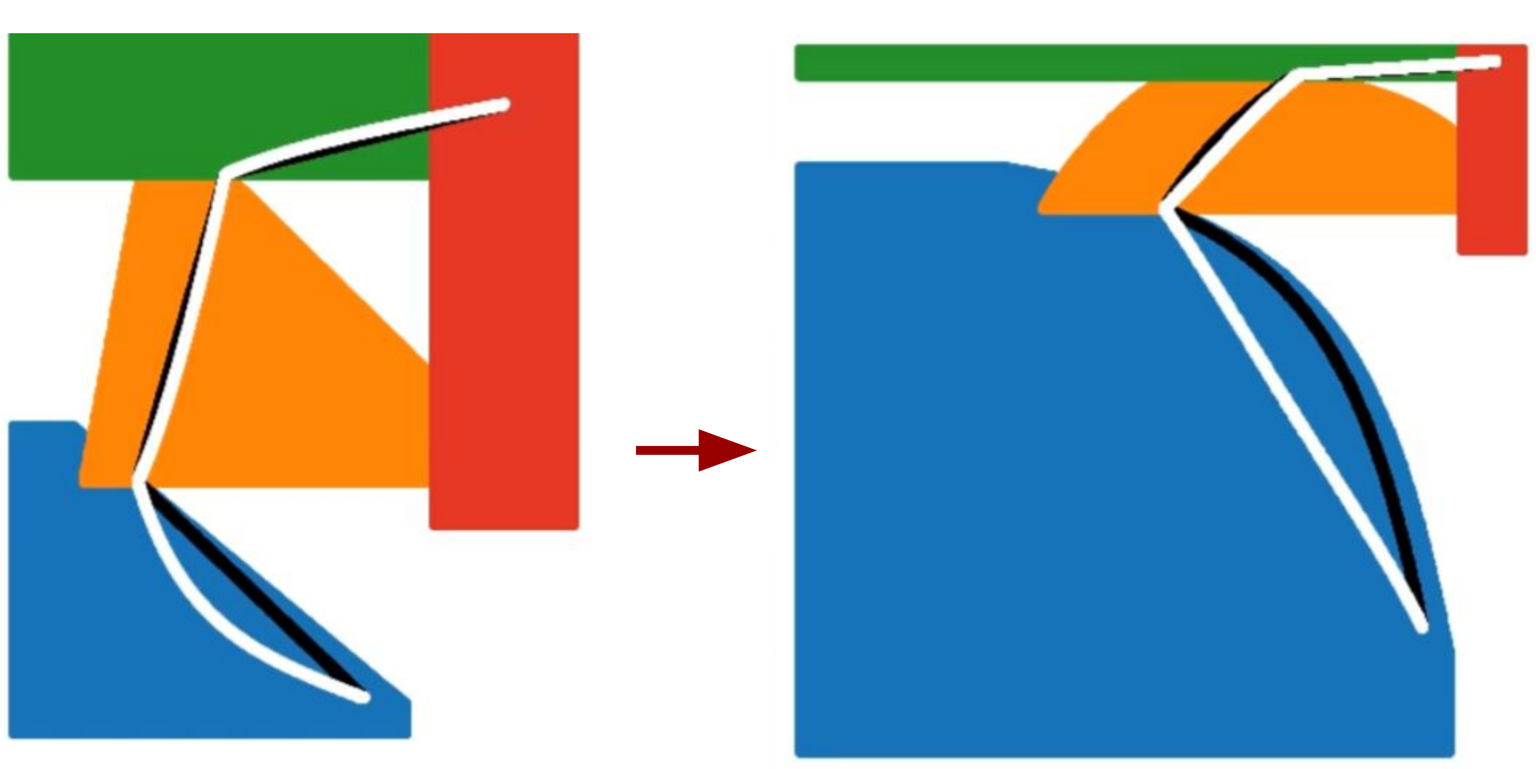
SUMMARY

- Confining non-convexity to objectives preserves feasibility, improves path metrics
- Projected Gradient Descent (PGD) — a first order solver — to exploit the structure
- Trajectory Optimization in key manipulation domains with GCS

Graphs of Convex Sets (GCS) in Parameterized C-Space



Planning Space C - Space

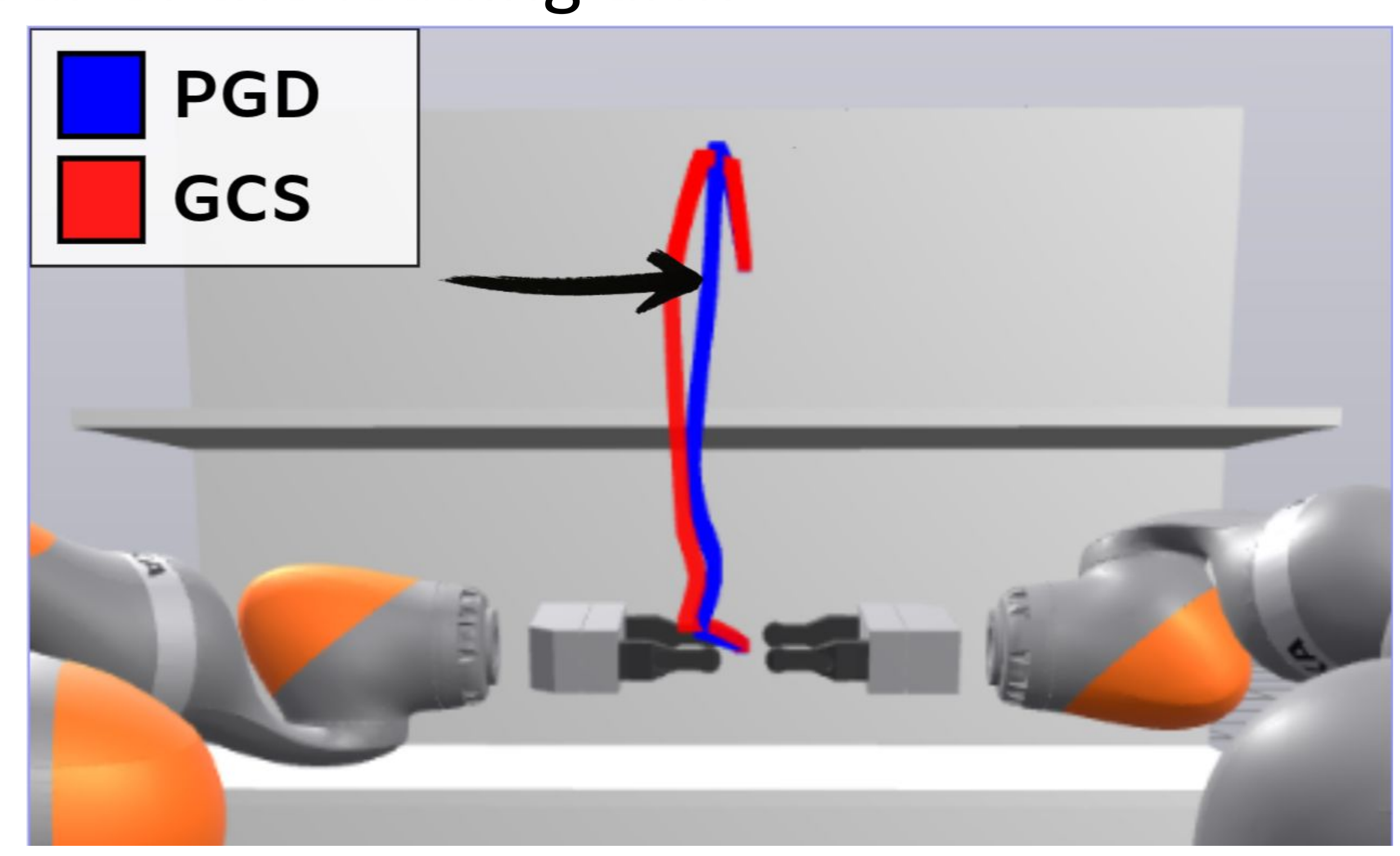
Mapping the Objective using α

$$\min_{\mathbf{x_v}} \sum_{i=0}^{v} \sum_{j=0}^{d} \|x_{ij} - x_{ij-1}\| \quad \text{s.t.} \quad x_i \in Q_i, \quad Q_i \in \mathcal{P}$$

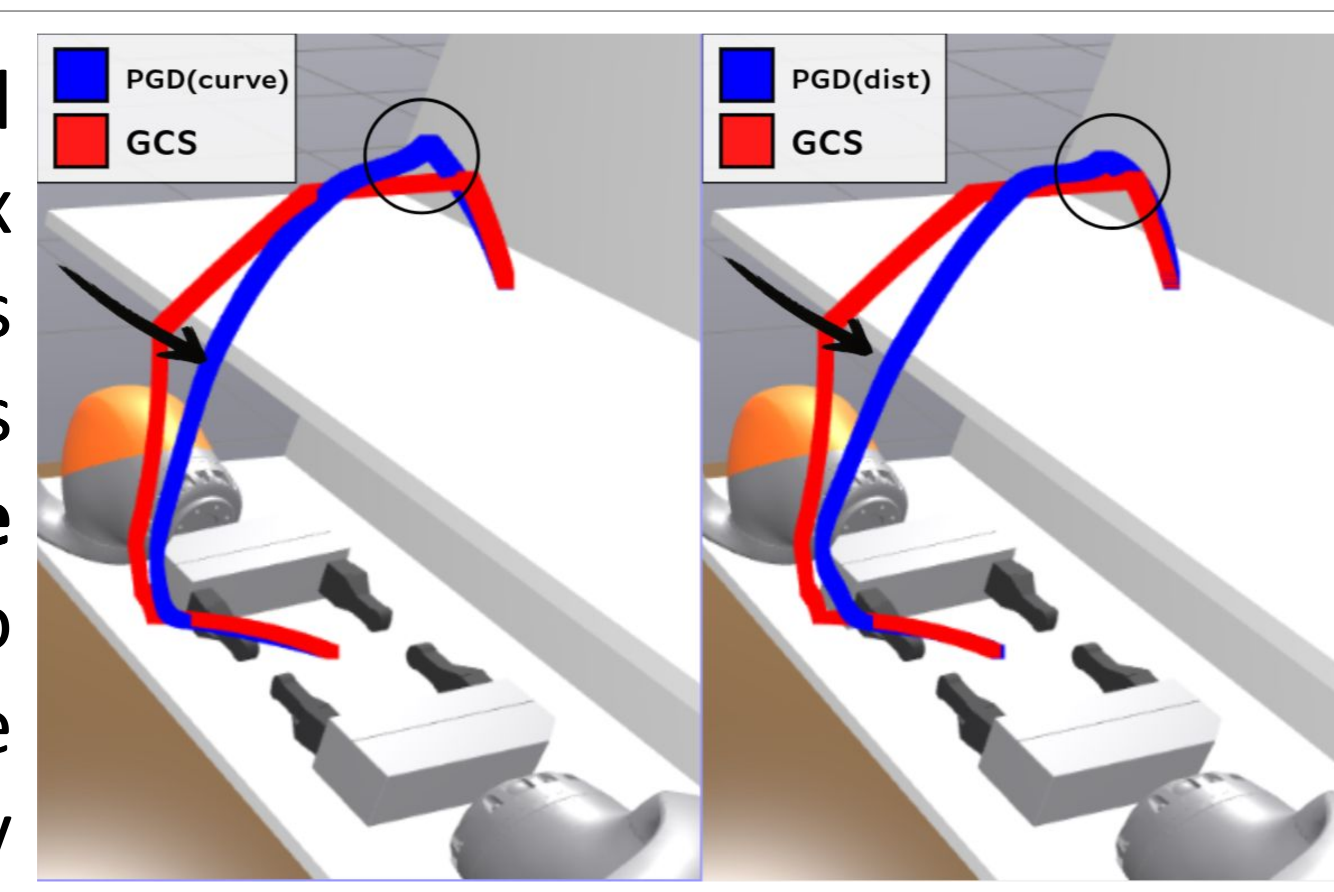
$$\min_{\mathbf{x_v}} \sum_{i=0}^{v} \sum_{k=0}^{10} f(\alpha(x_{ik}), \alpha(x_{ik-1}))^2 \quad \text{s.t.} \quad x_i \in Q_i, \quad Q_i \in \mathcal{P}$$

x_{ij} is the j^{th} control point of the Bézier curve in set Q_i
x_{ik} is the k^{th} sampled point in set Q_i
$f(a, b)$ gives the distance between two points a and b in C
Note both optimizations still operate in Q, the parameterized convex sets

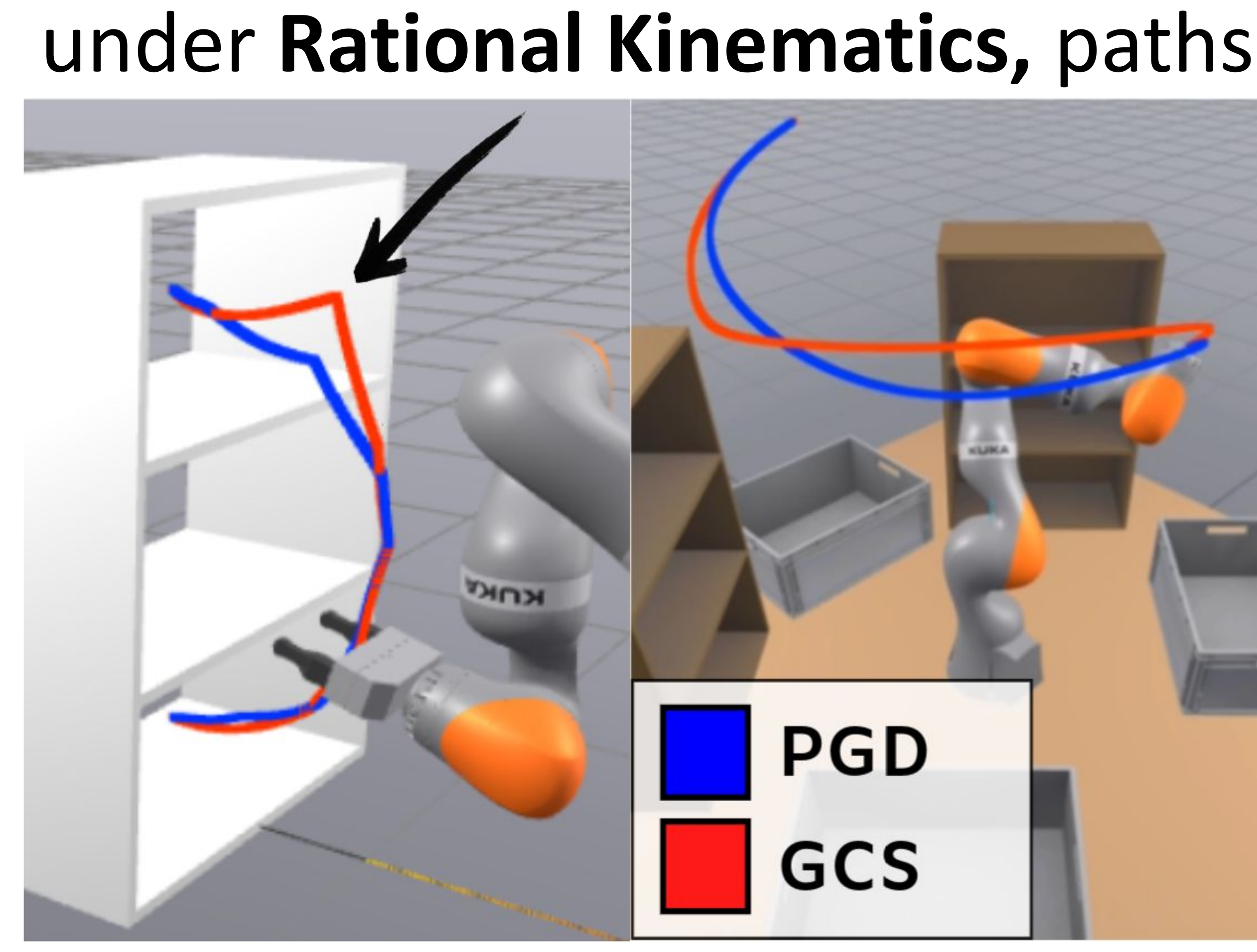
Constrained Bimanual Manipulation using **IK** plans paths in the leading arm's joint space (the subordinate arm follows). After out method, paths become <u>shorter</u> and <u>less skewed</u> in favour of the leading arm



General nonconvex objectives such as **Curvature** can also improve path quality



For **certified collision free IRIS regions** grown under **Rational Kinematics,** paths become <u>less skewed</u> towards the nominal position on both 3DoF and 7DoF simulated iiwas



<u>Reduced relative error</u> on shortest path length when planning **3D Rotations with Euler Angles**