KnotDLO: Toward Interpretable Knot Tying

Holly Dinkel[1,2], Raghavendra Navaratna[1], Jingyi Xiang[1], Brian Coltin[2], Trey Smith[2], Timothy Bretl[1]

[1]University of Illinois at Urbana-Champaign, Urbana, IL, USA [2]NASA Ames Research Center, Moffett Field, CA, USA

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Introduction

Composing pick-and-place actions designed from the geometry of a rope is enough to tie untightened knots such as the overhand knot. This in-progress work presents KnotDLO, a method toward one-handed knot tying that is robust to occlusion, repeatable for varying rope initial configurations, interpretable for generating motion policies, and requires no human demonstrations or training. Grasp and target waypoints for future rope states are planned from the current rope shape and are designed using four movement primitives from knot theory.

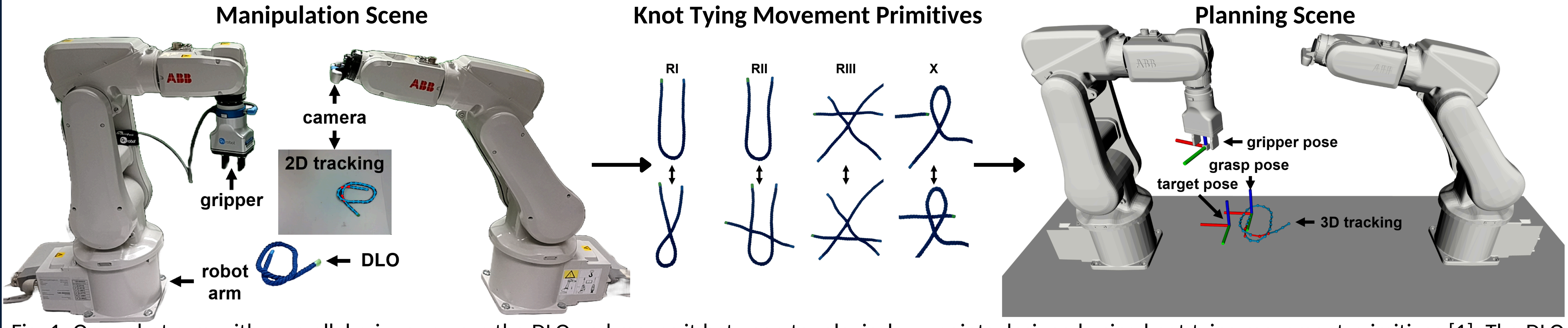

Fig. 1. One robot arm with a parallel gripper grasps the DLO and moves it between topological waypoints designed using knot tying movement primitives [1]. The DLO topology is tracked from imagery collected by a camera mounted on the last link of a second robot arm.

The KnotDLO Algorithm

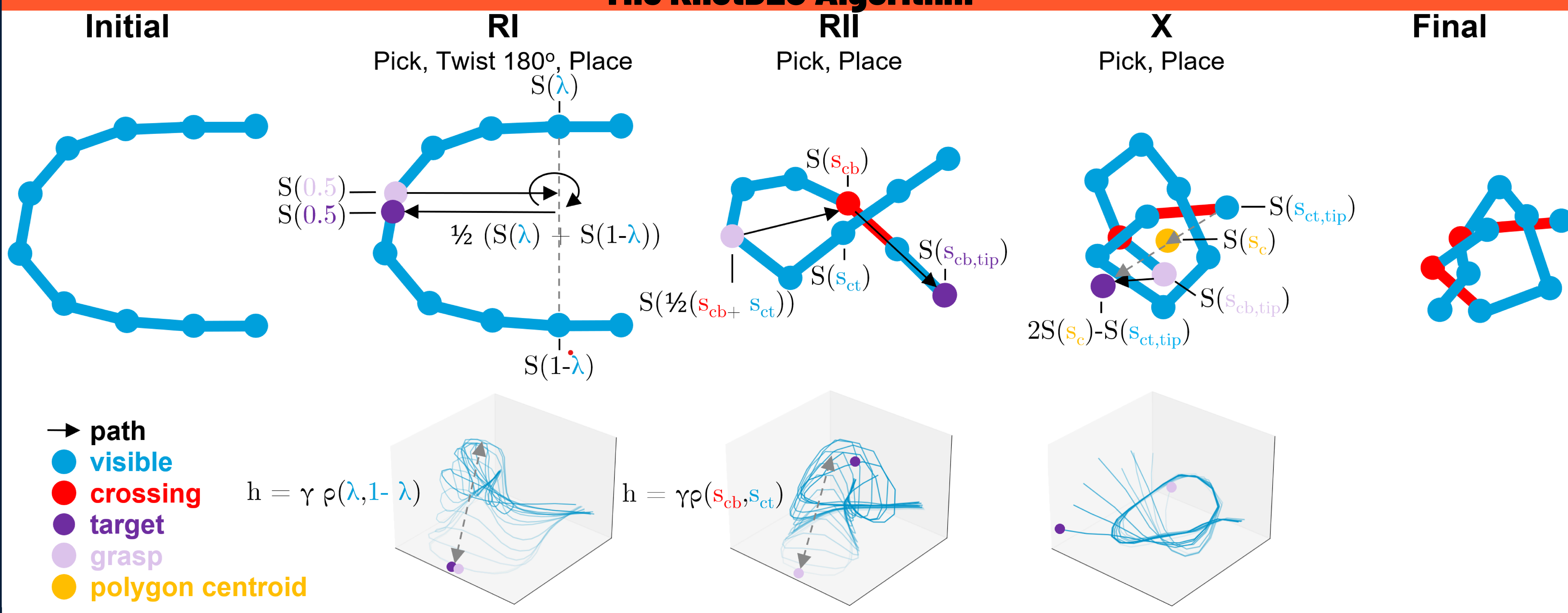

Fig. 2. Given an initial symmetric, curve-shaped DLO configuration, the planning system computes grasp and target indices from the topology to compose a sequence knot tying movement primitives. (Top) Sequentially performing Reidemeister Move I (RI), Reidemeister Move II (RII), and the Cross Move (X) results in an overhand knot. (Bottom) The tracking system tracks the shape of the DLO as it moves.

Curve Representation: $S : s \in [0,1] \rightarrow S(s^t; L) \in \mathbb{R}^3$

Curvilinear Length at time *t*: s^t

DLO total length: L

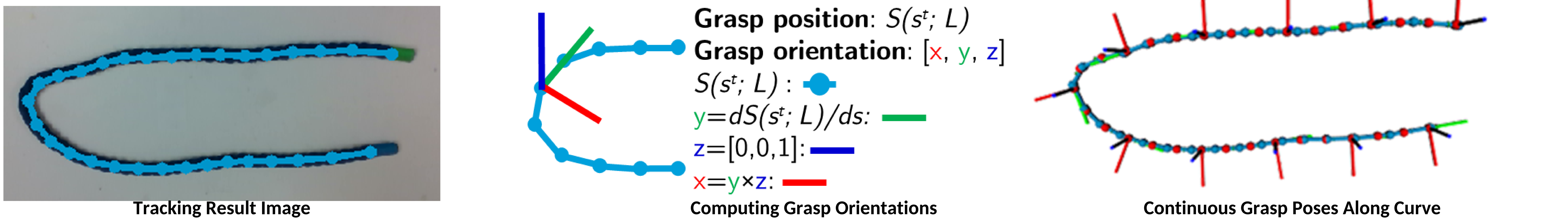

Fig. 3. A grasp pose can be computed given the curve representation of the tracking result, $S(s^t; L)$, and the curvilinear length at a given time step, s^t.

Experiments and Results

In 16 experiments analyzing the repeatability of one-handed knot manipulation, the system achieves a 50% success rate in tying an an overhand knot from previously unseen initial configurations. The system could be further improved by reducing noise in the planned waypoints poses and improving the robustness of estimating which nodes are occluded during tracking [2].

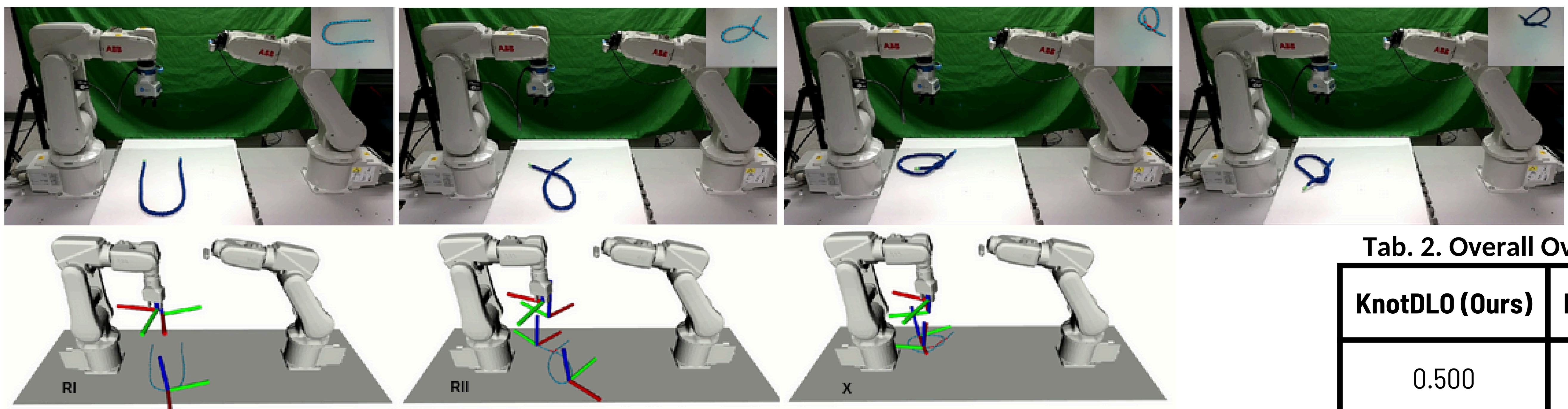

Fig. 4. A small number of waypoints designed based on the rope topology are required to tie an untightened overhand knot.

Tab. 1. Per Move Success Rate

RI	RII	X	Total
0.937	0.867	0.615	**0.500**

Tab. 2. Overall Overhand Knot Tying Success Rates

KnotDLO (Ours)	DDOD [3]	GSP [4]	Imitation [5]
0.500	**0.66**	0.6	0.38

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https://github.com/RMDLO

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