Motion Comparator: Visual Comparison of Robot Motions

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Synopsis: Motion Comparator is a web-based application to visualize, compare, and share robot motions.

Motivation

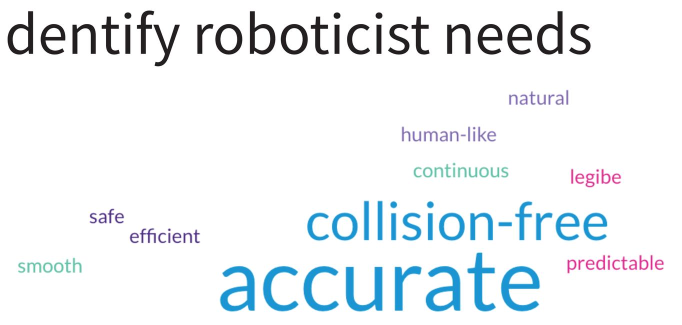
Roboticists compare robot motions for tasks such as parameter tuning, troubleshooting, and deciding between possible motions

Robot motions are temporally long, spatially complex data, and have complex relationships

Design Process

We design our system by applying a rigorous visual comparison design framework[1].

Identify roboticist needs



Motion properties extracted from the abstracts of 64,893 papers

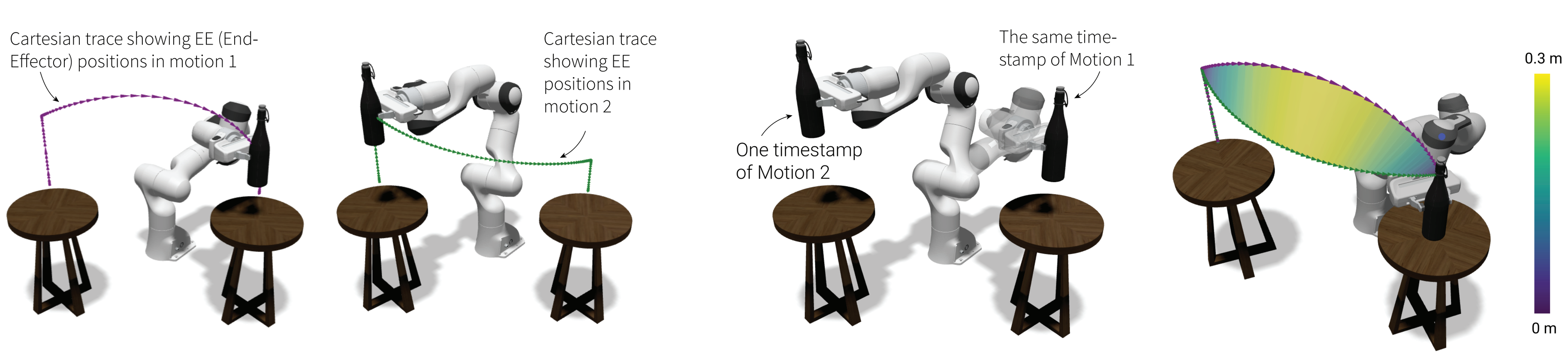
	Properties	Cartesian Space	Joint Space	Time
Objective	Efficiency			●
	Collision-Free/Safeness	●		
	Smoothness/Continuity	●	●	●
	Accuracy	●		
Subjective	Predictability	●		●
	Legibility	●		●
	Human-Like/Natural	●		●

Analyze comparative challenges and strategies

Challenges:
- Temporal length of robot motions
- Spatial complexity of robot motions
- Complexity of relationships

Strategies:
- Traces in various spaces
- Subset selection
- Multi-view coordination
- Temporal alignments

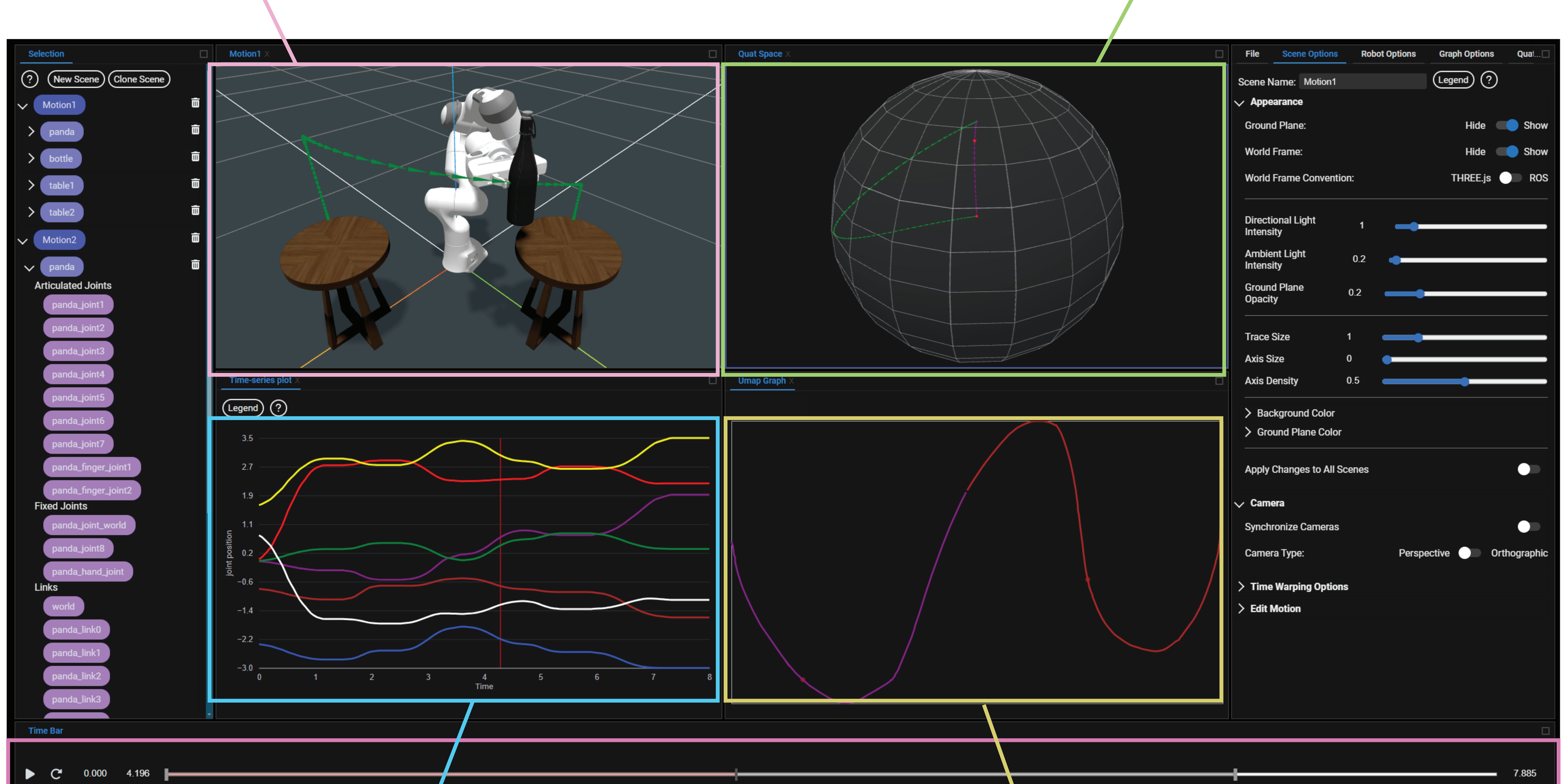
Consider comparative designs



Multi-View Interface

3D Scene: render robots and their surroundings in simulated 3D environments

Quaternion Space: visualize an object's orientation by projecting quaternions to a 3D space



Time-Series Plot: plot positions in joint space or Cartesian space and their derivatives (velocities, accelerations,and jerks)

Joint Trace: use a dimensionality reduction technology (UMAP[2]) to depict the movement of all joints of a robot in a line

Scrubbable Timeline Bar: enable multi-view coordination

Other Features

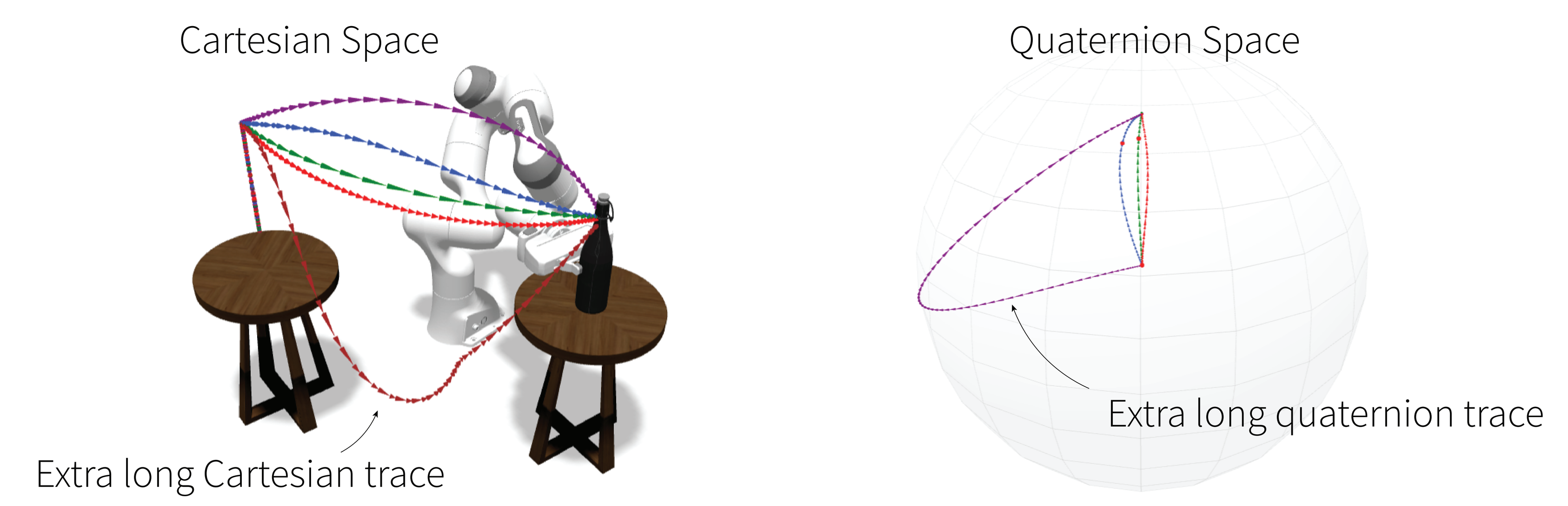
Web-based interface: lightweight, cross-platform and runs in a browser
ROS integration: directly parse rosbag files
Time warping: autonomous temporal alignment
Subset selection: easily select a subset of a motion by adjusting the selectable region of the timeline bar

Our tool is open-sourced!

Case Studies

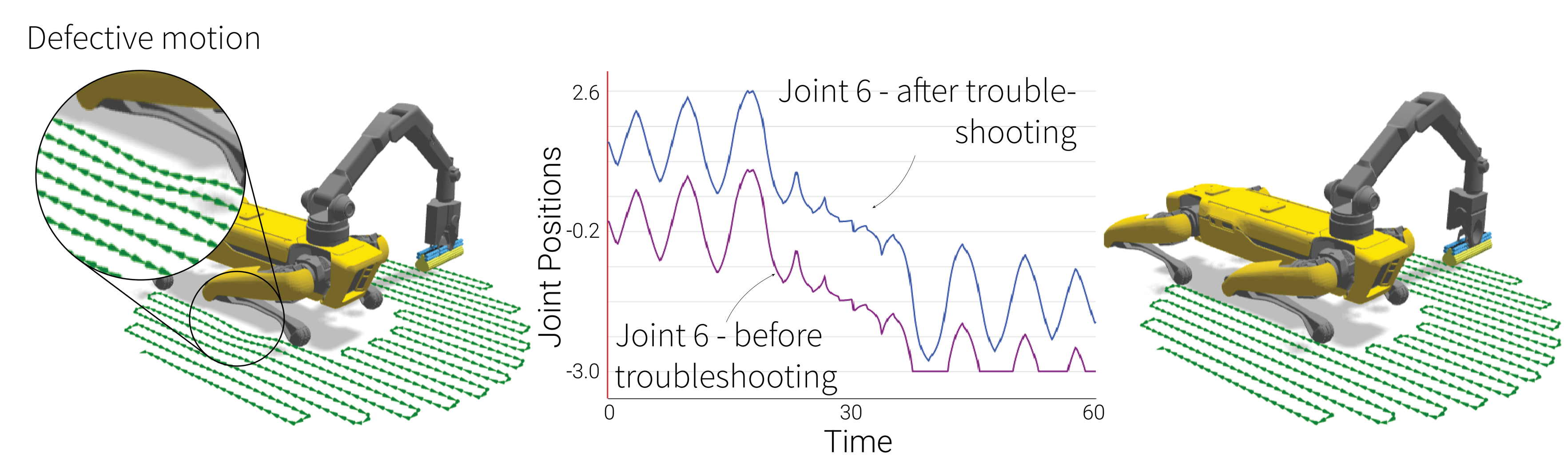
A. Motion Selection after Planning

Task: compare five motions generated using a sampling-based motion planner, TRRT[3]
Without MC: play each motion one by one in a visualization tool such as Rviz
With MC: quickly exclude extra long motions using position and quaternion traces



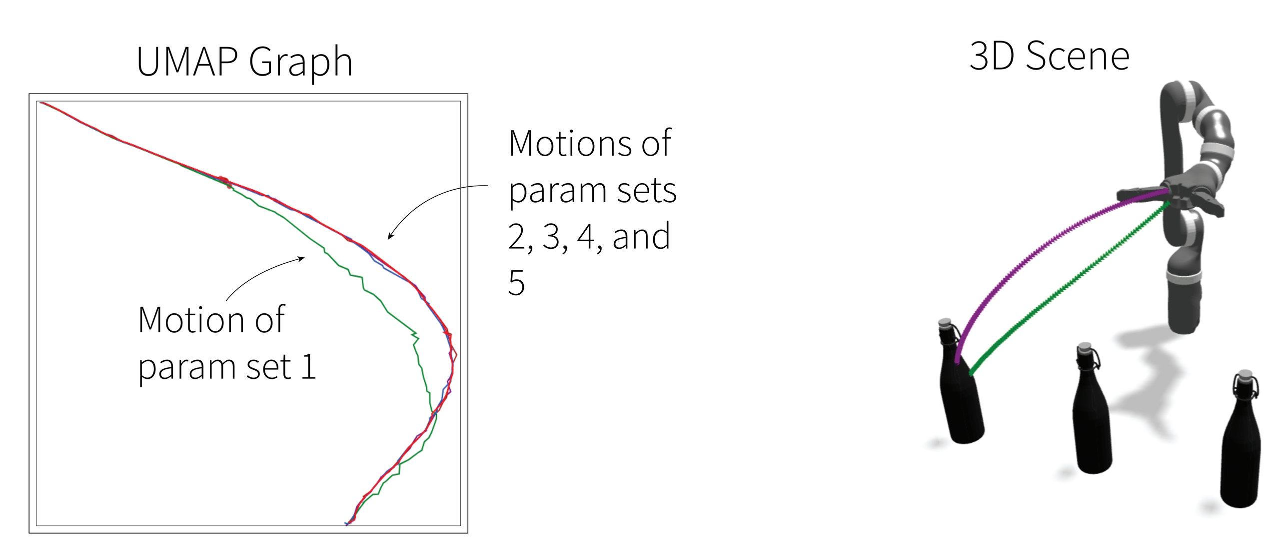
B. Troubleshooting

Task: a Spot robot wipes nearby areas using its arm
Without MC: manually develop code to inspect motions
With MC: identify the problem in the 3D scene, navigate to the problematic segment using the time-line bar, and troubleshoot using a time-series plot



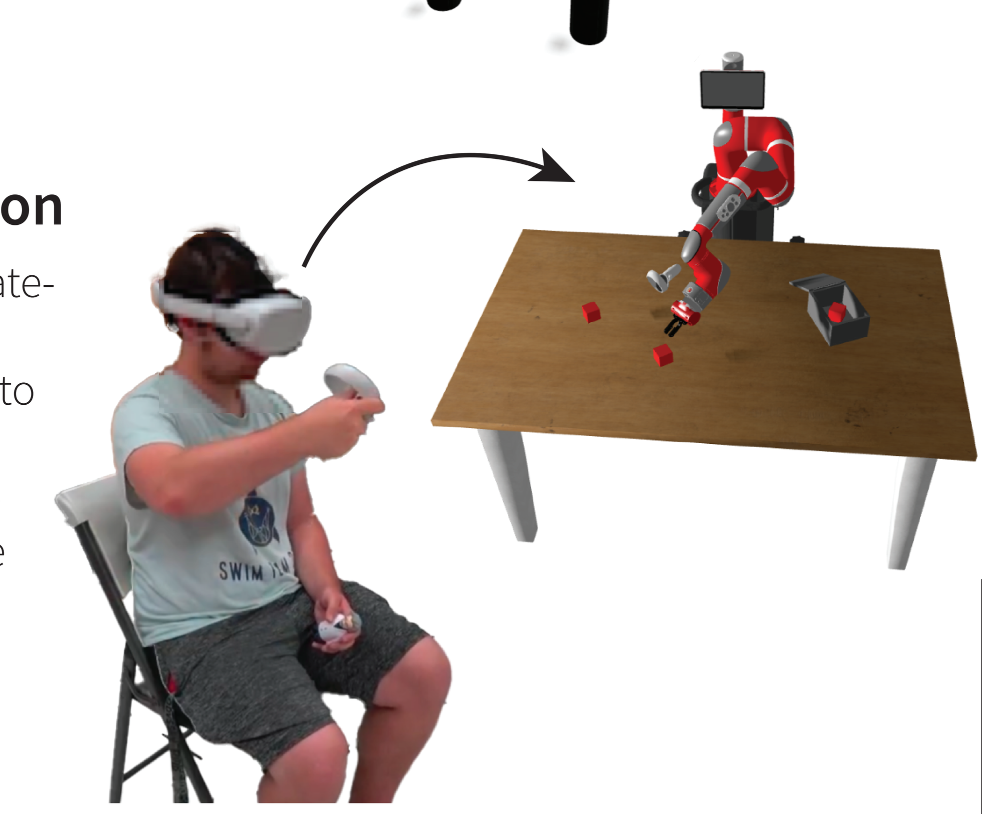
C. Parameter Tuning for Legible Motions

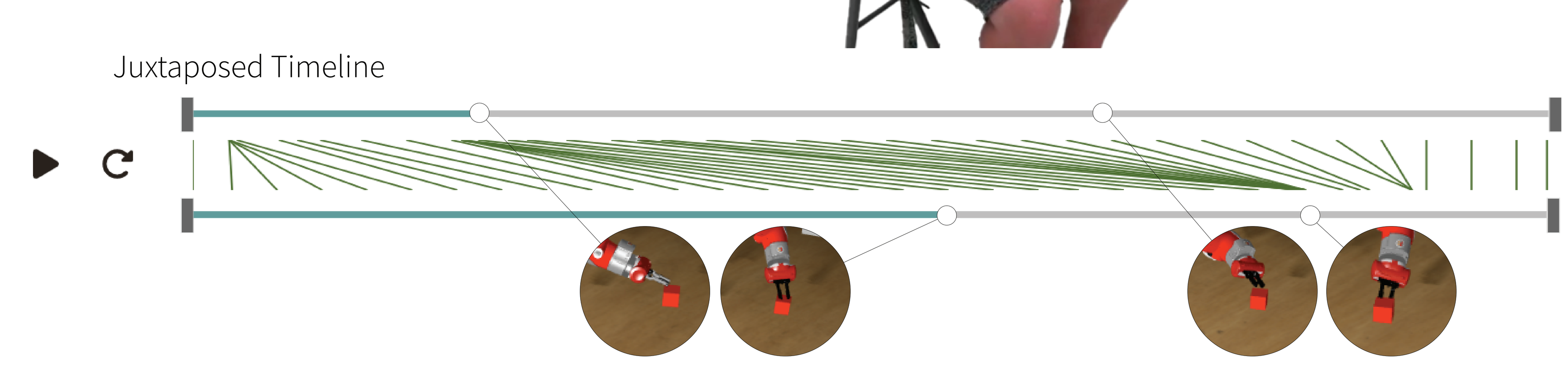
Task: compare five legible motions generated using different parameter sets (legible motions[4] clearly communicate the robot's intentions to humans)
Without MC: initiate five instances of visualization tools (e.g., Rviz) side-by-side, manually synchronize the camera viewpoints, and manually align the motions in time
With MC: the UMAP graph view shows that the motions generated by four parameter sets are close to each other. Instead of comparing all five motions, the roboticist only compares two of them in the 3D scene



D. Review of Motions in Teleoperation

Task: gain insights into different teleoperation strategies, e.g., the ways to pick up a block
Without MC: manually navigate through motions to observe how the robot picks up a block
With MC: the time warping feature enables the roboticist to quickly align two motions and compare various ways to pick up a block





[1] Michael Gleicher, Danielle Albers, Rick Walker, Ilir Jusufi, Charles Hansen, and Jonathan Roberts, "Visual comparison for information visualization", IV'11
[2] Leland McInnes, John Healy, and James Melville, "UMAP: Uniform Manifold Approximation and Projection for Dimension Reduction", ArXiv'18
[3] Didier Devaurs, Thierry Simeon and Juan Cortes, "Enhancing the transition-based RRT to deal with complex cost spaces", ICRA'13
[4] Christopher Bodden, Daniel Rakita, Bilge Mutlu and Michael Gleicher, "A flexible optimization-based method for synthesizing intent-expressive robot arm motion", IJRR'18

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