On Use of Nav2 MPPI Controller

Steve Macenski, Open Navigation LLC
Launching Nav2, ROS, and the Community into the Future!

- Your Friendly Neighborhood Navigators!
- Develop & Maintain Open-Source Mobile Robotics, Long-Term
- Sponsored by Those Using ROS / Nav2 for Products & Services
- Offering Support Services to Power Users’ Success

Looking for Additional Sponsors and Partners!
- Find me after the talk or email me at info@opennav.org
Background - Trajectory Planning

“How Do I Follow This Objective?”

Trajectory Planning Aims to:
- Track paths or goals
- Avoid obstacles
- Compute feasible commands
- Optimize for behavioral objectives
- Achieve goal(s) with high accuracy

This is the Behavior of a Robot a Person Sees
- Important beyond engineering metrics!

Many Types of Approaches Exist
- Solve for 1+ or all of the aims
- MPC, DWA, PP, Splines, Primitives, APF
Background - ROS Trajectory Planning

What Options Did We Have Before?

Navigation Stack
- Base Local Planner
- DWA Local Planner

Nav2
- DWB Controller
- Reg. Pure Pursuit Controller
- Rotation Shim

The Community
- TEB Local Planner
- Graceful

→ No Contemporary Approaches

Common Complaints

“The Nav Stack keeps running into walls.”

“Why does my robot get stuck so much?”

“God, tuning this is such a pain!”

“Recoveries are constantly triggering”

“I wish I went to medical school instead…”

The root cause is usually the trajectory planner *

See a full comparison “From the Desks of ROS Maintainers: A Survey of Modern & Capable Mobile Robotics Algorithms in the Robot Operating System 2”   * Or a desire for a career change
Sampling-Based Model Predictive Control

1. Add Noises to Prior Optimal Trajectory’s Controls
2. Apply Dynamics to Controls & Rollout Trajectories
3. Score Noised Trajectories Via Objective Functions
4. Compute New Optimal Control Sequence
5. Execute First Control, Shift Optimal Control. Repeat.
Sampling-Based Model Predictive Control

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Looks like this!
Sampling-Based Model Predictive Control

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MPPI Controller - Concept

Sampling-Based Model Predictive Control

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Find more information: “Information Theoretic Model Predictive Control: Theory and Applications to Autonomous Driving”
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→ No Derivatives or Required Objectives Convexity
→ Arbitrary Dynamics, Constraints, and Objectives
MPPI Controller - Overview

Model Predictive Path Integral Controller

- Cutting-Edge Predictive Controller Used in AV’s
- Emergent Intelligent Behaviors - *Far* Fewer Recoveries
- Circular, Non-Circular, Legged, Ackermann, Diff & Omni
- Plugin-Based Critic Functions For Behavioral Expansion
- 97% Unit Test Coverage, Used in Production Today
MPPI Controller - More Details

**Designed to be the Last I’ll Ever Write** - famous last words

Tuned for Great Out-of-the-Box Performance!

Superior in Tricky Situations, Highly Flexible

Accepts Feasible Paths, Respects Path Inversions

CPU-Only @ 30-50 Hz, No GPU Lock-In

Future Improvements + Innovations in Research
→ CPU speed, GPU support, smoothness, dynamics models, addtl critics, …

**Major Thanks to Alexey Budyakov (@artofnothingness)**
Original Prototype Author & Proactive Collaborator
MPPI Controller - Configuration

See README For Details & Guidance

10 Optional Critics

3 Motion Models

Batch Size - # of Sampled Trajectories
Time Steps - # of Time Steps in Trajectories
Model dt - Δt between Trajectory Time Steps

Tuned: 30Hz @ 2000, 50Hz @ 1000

Costmap Smooth Inflation Critical! (like Smac)

Sampling STD \( \{V_x, V_y, W_z\} \) - Sampling Noise
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