Code Generation and Conic Constraints for Model-Predictive Control on Microcontrollers with Conic-TinyMPC

Ishaan Mahajan*, Khai Nguyen*, Sam Schoedel*, Elakhya Nedumaran, Moises Mata, Brian Plancher, and Zachary Manchester

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The Big Picture:

- **Conic-TinyMPC** extends TinyMPC from QP-only embedded MPC to second-order cone programs.
- **Closed-form cone projections** keep cached ADMM fast, warm-started, and MCU-ready.
- **Codegen emits dependency-free C++** from Python, MATLAB, and Julia problem specs.
- **10.6x-142.7x speedups** vs. embedded solvers.

tinympc.org

docs, code, and examples

Background:

• MPC needs constraints for real robots: thrust cones, glideslope limits, actuator bounds, friction cones, and safe workspaces.

• Tiny platforms need static memory, warm starts, no dynamic allocation, and low solve latency.

• Conic-TinyMPC is the paper's SOC-capable, warm-started, embedded, open-source MPC-tailored solver.

Core ADMM split

z = Primal LQR step

s = Cone slack step

λ = Dual update

Compressed ADMM keeps each online sweep lightweight

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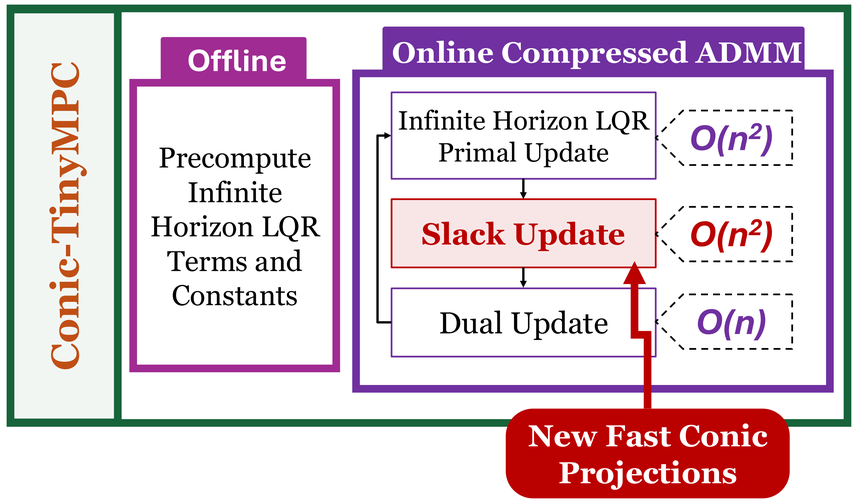
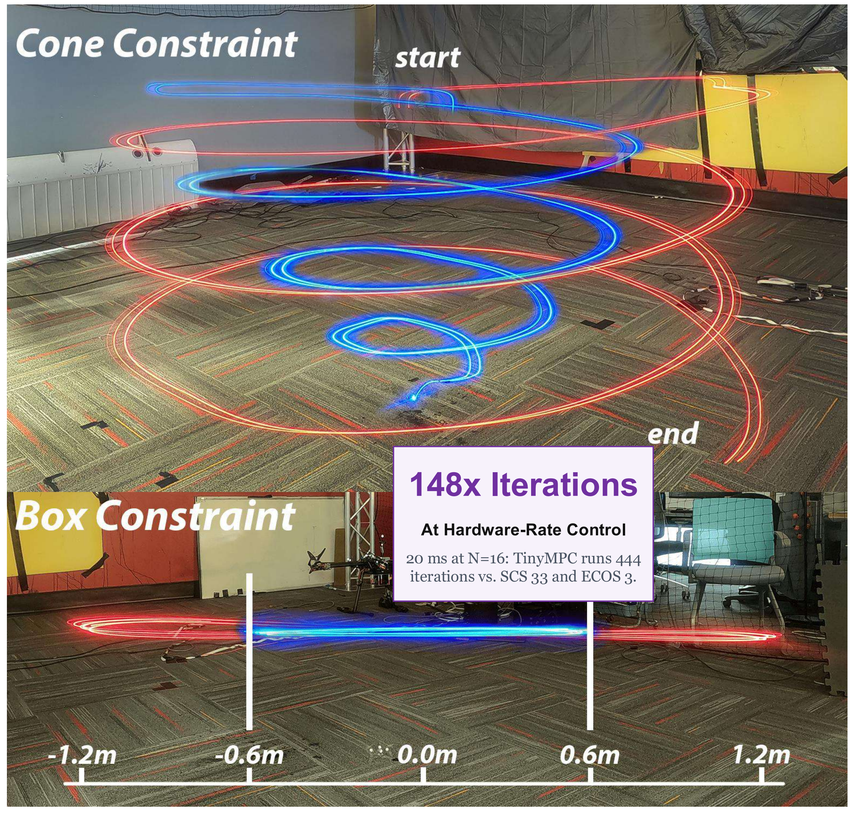
Algorithmic Approach:



Hardware Validation:

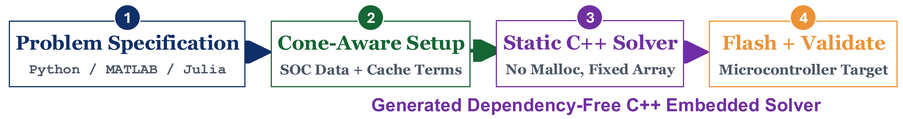


148x Iterations

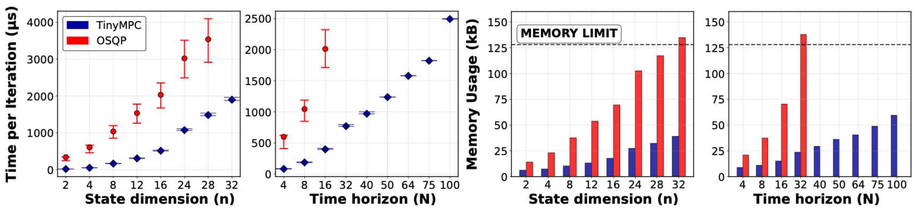
At Hardware-Rate Control

20 ms at N=16: TinyMPC runs 444 iterations vs. SCS 33 and ECOS 3.

Code Generation Workflow:



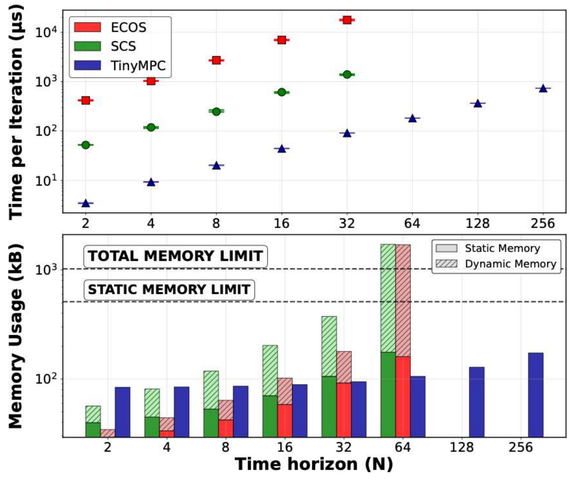
Experimental Results:



20.4x Faster

Safety Filter vs. OSQP

QP safety filter on STM32F405 at N=100; OSQP exceeds memory at N=32.



N=256

largest SOCP horizon solved

Conic-TinyMPC solves N=256; SCS and ECOS exceed memory at N=64.

142.7x Faster

SOCP rocket landing

Teensy 4.1 benchmark: 13.8x faster than SCS and 142.7x faster than ECOS.

Recent Extensions:

TinySDP: Certifiable Safety

Semidefinite Relaxations for Onboard Obstacle Avoidance:
31-73% shorter paths; 25 Hz certificate on MCU

nonconvex obstacles → Lifted PSD MPC → rank-1 certificate

Adaptive Caching Framework

Cache-Free Online Penalty Tuning:
63% fewer ADMM iterations
47% faster mean solve time

Offline Sensitivities → O(n²) cache update → tuned ADMM