Agile Event-based Flight through Cluttered Environments

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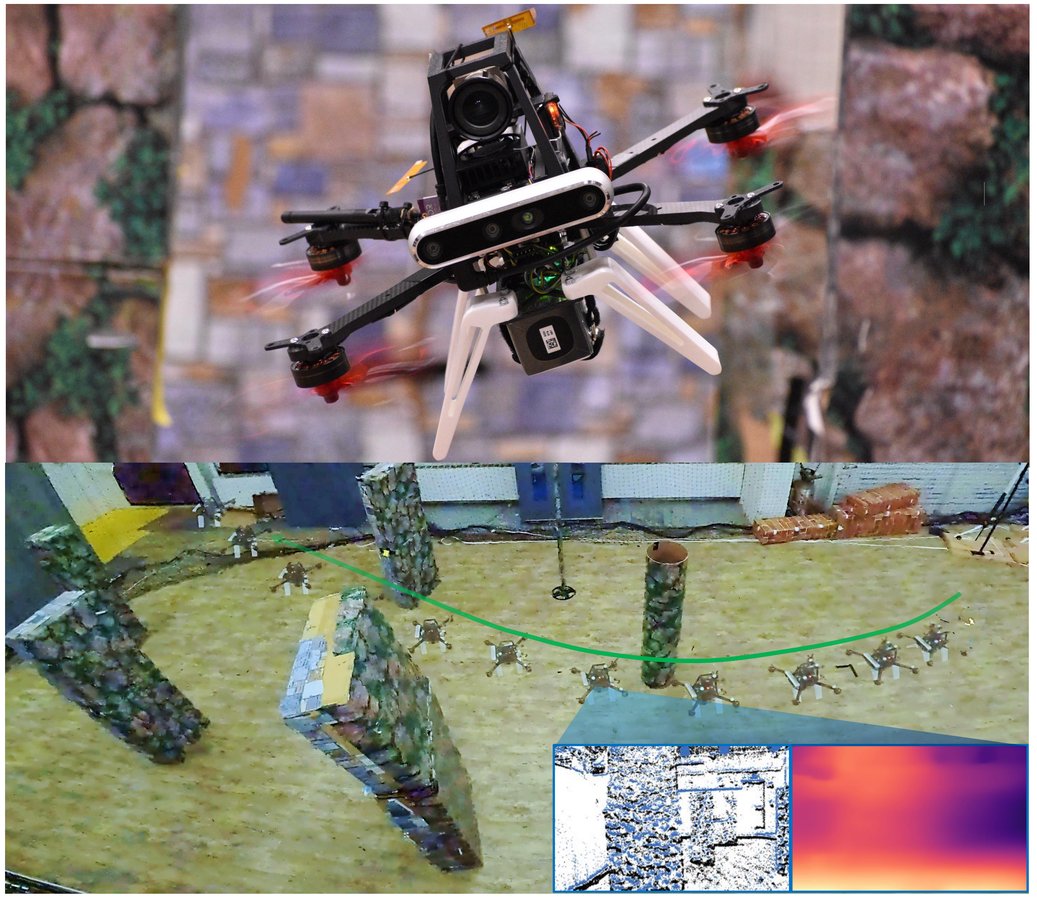
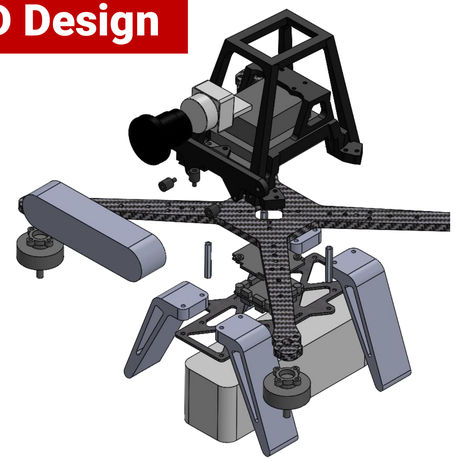
Motivation

- In search-and-rescue and anti-poaching, event cameras drive high-speed autonomous MAV navigation through high temporal resolution, high dynamic range, and low latency.
- Current systems are limited by bulky cameras, power capacity, and perception latency (1µs vs 33ms)



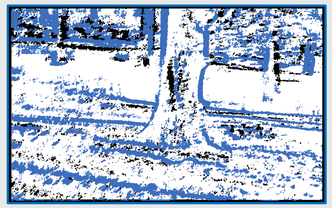
3D Design



Technical Details

- We build ESDF maps using predicted depth from events and robot states
- We use a **kinodynamic trajectory optimizer** with ESDF maps and B-splines to generate smooth, collision-free trajectories.
- DQ-NMPC is a dual-quaternion nonlinear MPC that performs constraint-aware trajectory tracking on SE(3).

Event Stream



Event Camera Formulation

$$L(\mathbf{x},t) = \log I(\mathbf{x},t)$$
$$\Delta L(\mathbf{x},t) = L(\mathbf{x},t) - L(\mathbf{x},t-\Delta t)$$
$$\text{ON event: } \Delta L(\mathbf{x},t) \geq C$$
$$\text{OFF event: } \Delta L(\mathbf{x},t) \leq -C$$

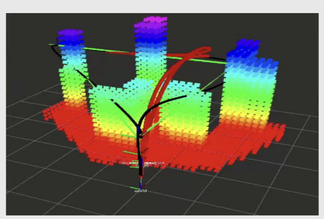
Depth Prediction (F^3)

Deep Set Encoding

$$\underbrace{\Phi(\mathcal{E})}_{\text{set representation}} = \underbrace{\rho}_{\text{post-processing}}\left(\underbrace{\sum_{x\in\mathcal{E}}\psi(x)}_{\text{pool per-event features}}\right)$$

Perception

FastPlanner



$[\tau_d,\ \Omega_d]$ → **DQ-NMPC** → $[f,\ w]$ → **Body-Rate Controller**

Motion Capture

Visual Inertial Odometry

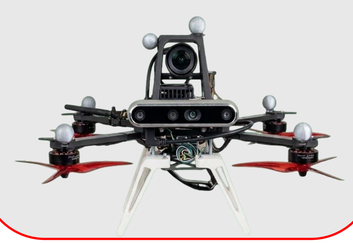
$\boldsymbol{x}$

Kinodynamic Planner Cost Functions

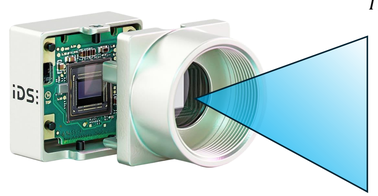
$$x(t) = e^{At}x(0) + \int_0^t e^{A(t-\tau)}Bu(\tau)\,d\tau$$
$$\mathcal{J}(T) = \int_0^T \|u(t)\|^2\,dt + \rho T$$

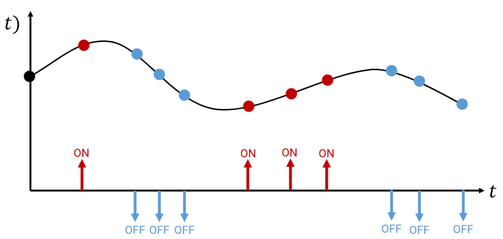
Planning & Control

Hardware Platform



Event Camera Sensor





FastPlanner to DQ-NMPC Controller