Learning Perception-Aware Agile Flight in Cluttered Environments

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ROBOTICS & PERCEPTION GROUP

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1. Motivation

- Autonomously navigating quadrotors through cluttered environments as fast as possible
- Minimum-time flight requires the vehicle to operate on the edge of its physical limits and perceptual limits
  - high speeds and accelerations
  - limited field of view and motion blur
  - limited sensing range
  - limited computation

2. Methodology

Learning state-based teacher policy

- Combine curriculum reinforcement learning with topological path planning
- Perception aware reward

$$r_{pa} = \exp(-\|\boldsymbol{\theta}_{\boldsymbol{yaw}} - \boldsymbol{\theta}_{\boldsymbol{dir}}\|),$$

- Parallelized environment (x100)

Learning vision-based student policy

- Encode depth images using an autoencoder

$$L(\theta, \phi) = \frac{1}{T} \sum_{t=1}^{T} \|\boldsymbol{I}(t) - \boldsymbol{D}_{\boldsymbol{\theta}} \left(\boldsymbol{E}_{\boldsymbol{\phi}} \left(\boldsymbol{I}(t)\right)\right)\|_2^2$$

- Train a control policy using imitation learning

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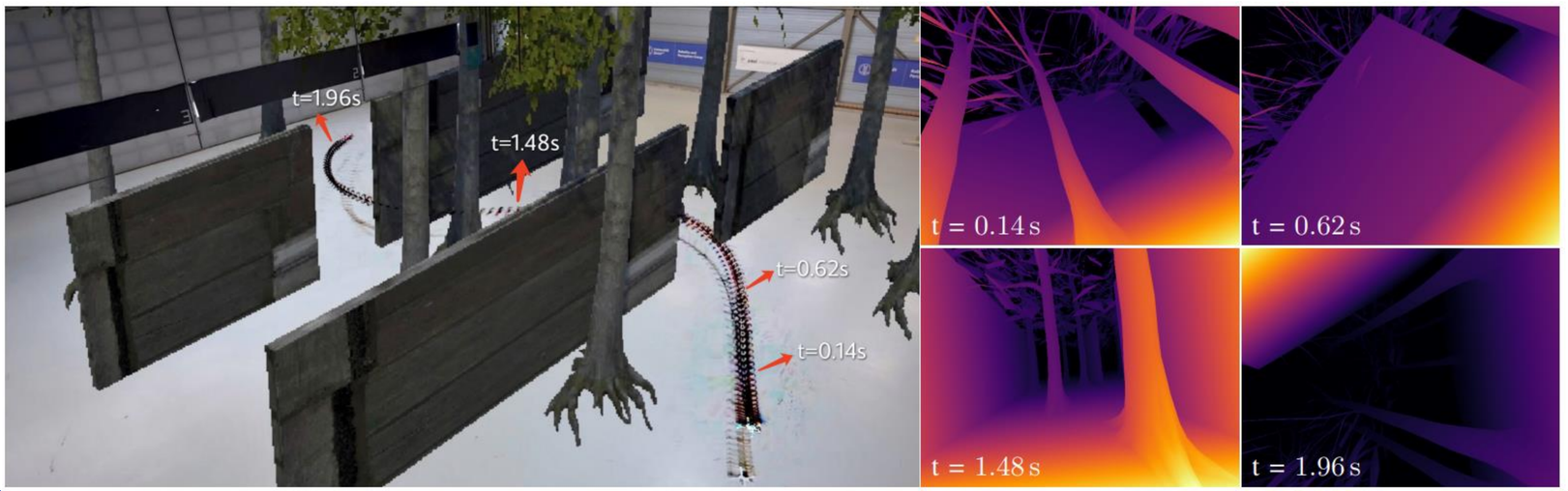
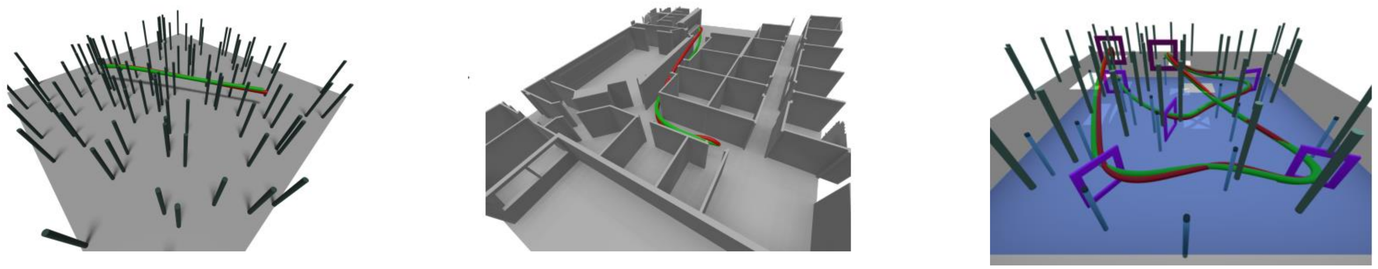
3. Hardware-in-the-loop Flight : Physical drone, Virtual environment, and Closed-loop control



3. Baseline Comparison: Planning + MPC versus RL



Environment	Case	Non-perception-aware: Sampling-based [32] + MPC [33] Success[%]	Non-perception-aware: Sampling-based [32] + MPC [33] Time[s]	Non-perception-aware: State-based [6] Success[%]	Non-perception-aware: State-based [6] Time[s]	Perception-aware (ours): State-based (teacher) Success[%]	Perception-aware (ours): State-based (teacher) Time[s]	Perception-aware (ours): Vision-based (student) Success[%]	Perception-aware (ours): Vision-based (student) Time[s]
Columns	0	25	1.22	100	**1.10±0.02**	100	1.16±0.02	100	**1.10±0.02**
	1	0	-	100	**1.10±0.02**	100	**1.10±0.03**	100	**1.10±0.03**
	2	27	1.14	100	**1.10±0.02**	100	**1.10±0.02**	100	**1.10±0.03**
	3	16	1.70	100	1.40±0.04	100	1.46±0.04	100	**1.39±0.04**
Office	0	41	2.38	100	1.80±0.04	100	1.92±0.04	100	**1.79±0.04**
	1	28	1.86	100	1.80±0.03	100	1.82±0.02	100	**1.76±0.02**
	2	56	2.29	100	**1.62±0.02**	100	1.66±0.03	100	1.63±0.03
	3	70	2.16	100	1.46±0.02	100	1.48±0.02	100	**1.45±0.02**
Racing	0	57	1.61	100	1.33±0.03	100	**1.32±0.02**	100	1.33±0.03
	1	51	1.64	100	**1.30±0.02**	100	1.42±0.03	100	1.31±0.04
	2	76	1.72	100	**1.42±0.02**	100	1.44±0.02	100	1.43±0.02
	3	54	1.80	100	1.42±0.02	100	1.48±0.02	100	**1.39±0.01**