Race Against the Machine

A Fully-annotated, Open-design Dataset of Autonomous and Piloted High-speed Flight

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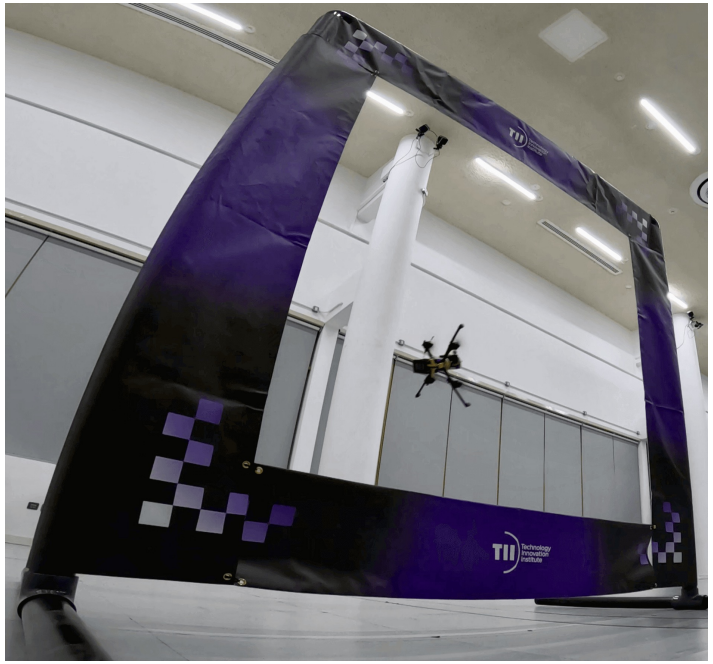


The Dataset in a Nutshell

- Fast (>20m/s) and aggressive quadrotor flights
- Autonomous and human-piloted flights
- Multiple trajectories
- Visual, inertial, and motion capture data
  - high-resolution
  - high-frequency
- Drone racing gates
  - bounding boxes
  - individual corner labels
- Control inputs and battery voltages

Why a New Drone Racing Dataset?

TABLE I: Comparison of multi-rotor and drone racing datasets for visual-inertial odometry, scene understanding, and control

Ref.	Time & Distance	Data Coll.	Conditions: Scene	Conditions: Lighting	Gates: Pose	Gates: Labels	Top Speed	Vision/Camera Specifications: Resolution/Freq.	Vision/Camera Specifications: Color	Vision/Camera Specifications: FoV	Vision/Camera Specifications: Stereo	Vision/Camera Specifications: Event	Pose/Inertial Data: IMU	Pose/Inertial Data: MoCap	Control Inputs: CTBR	Control Inputs: Motor	Battery Voltage	Data Formats
Ours	∼25' ∼8km	Real	Indoor	3 Levels Labeled	✓	✓†	9.5m/s◇ 21.8m/s¶	640x480@120Hz	RGB	155°	✗	✗	@500Hz	@275Hz	@100Hz	@100Hz	@50Hz	rosbag, CSV, JPEG
[2]	∼22' ∼10km	Real	Indoor; Outdoor	Multiple, Unlabel.	✗	✗	12.8m/s◇ 23.4m/s◇	346x260@50Hz 640x480@30Hz*	Grayscale Grayscale	120° 186°	✓	✓	@500Hz @1000Hz	@20Hz§	✗	✗	✗	rosbag, TXT, PNG
[5]	n/a‡	Real	Indoor, 1 Gate	Multiple, Unlabel.	✗	✓‖	n/a	1296x864	RGB	n/a	✗	✗	✗	✗	✗	✗	✗	JSON, JPEG
[6]	∼10h ∼100km	Real + Synth.	Indoor, 5 Scenes	Multiple, Unlabel.	✗	✗	7m/s	1024x768@120Hz†† 1024x768@360Hz††	Grayscale RGB	60°	✓	✗	@100Hz	@360Hz	✗	@190Hz	✗	rosbag, CSV, MP4, PNG Depth
[7]	∼22' ∼1km	Real	Indoor, 2 Scenes	Multiple, Unlabel.	✗	✗	2.3m/s	752x480@20Hz	Grayscale	115°	✓	✗	@200Hz	@20Hz§ @100Hz	✗	✗	✗	CSV, PLY, PNG
[8]	∼10' ∼3km	Real	Outdoor; 1 Scene	Multiple, Unlabel.	✗	✗	17.5m/s	960x800@40Hz	Grayscale	n/a	✓	✗	@200Hz	✗	✗	✗	✗	rosbag
[9]	∼300' ∼100km	Synth.	Indoor, 2 Scenes	Multiple, Unlabel.	✓	✓¶¶	13.8m/s	800x600@60Hz	RGB	120°	✗	✗	✗	@500Hz**	@500Hz	✗	✗	CSV, MP4
[10]	∼75'	Real	n/a	✗	✗	✗	18m/s	✗	✗	✗	✗	✗	@1000Hz	@400Hz	✗	@1000Hz	@400Hz	CSV

†Bounding boxes, top-bottom left-rigth corners. ◇Piloted. ¶Autonomous. *Stereo. §Leica laser tracker. ‡9300 frames.
‖Internal corners. ††Synthetic camera images. ¶¶Area of interest of the gaze. **Simulated.

Reproducibility

Release of

- Design of the drone used to collect the data
  - Bill of Material, 3D models, building tutorial
- Reference controller code used for autonomous flight
- Betaflight parameters

Racing drone features

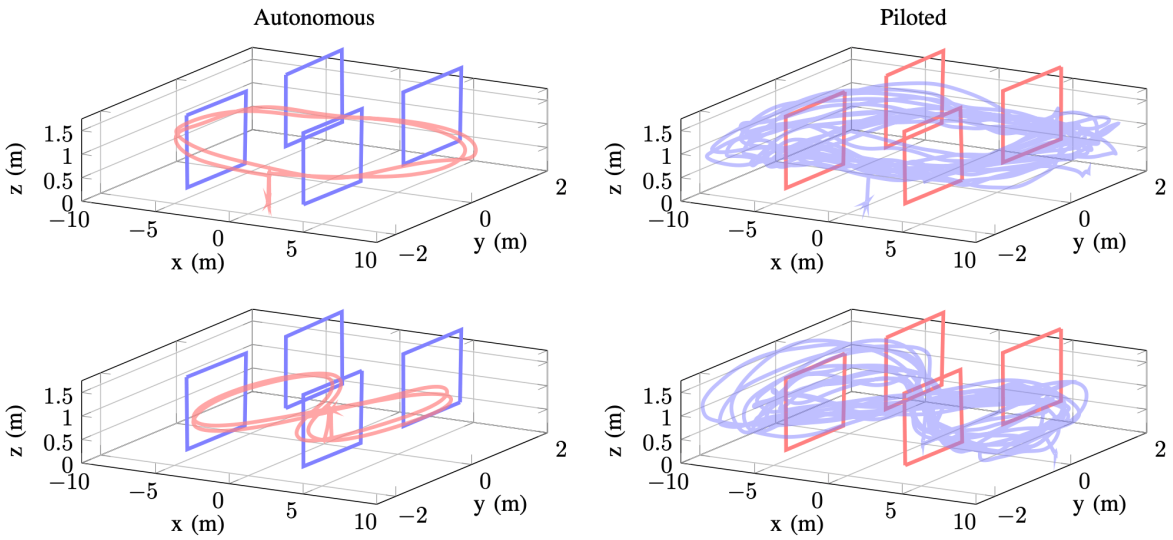
- Powerful embedded computer
- Agility and speed (up to 179km/h)
- Allows both autonomous and piloted flight

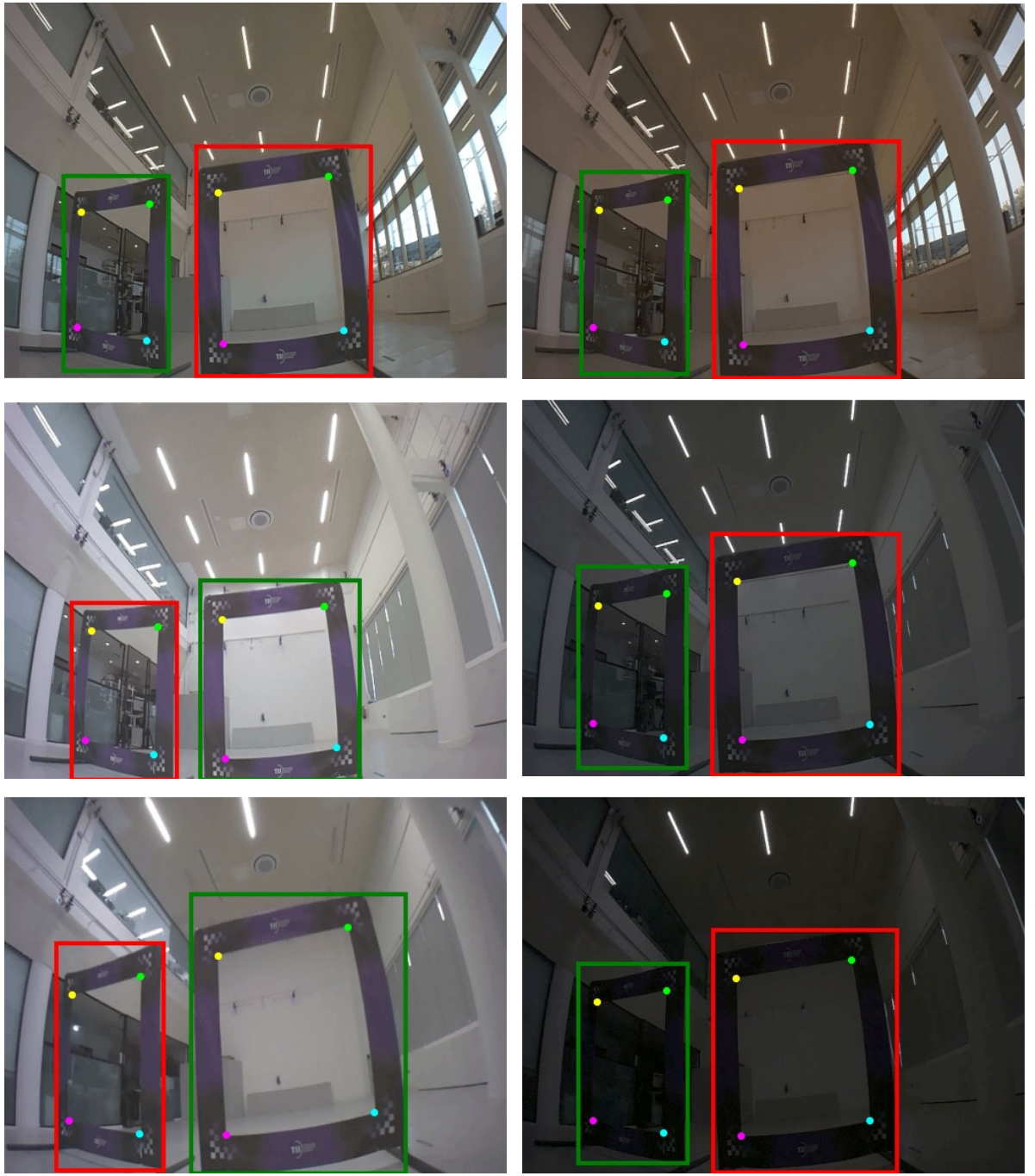
Recorded Flights

TABLE III: Summary of the flights recorded in the dataset

Control	Shape	Top Speed	Time	Distance
Autonomous	Ellipse†	**21.83 m/s**	149.32 s	526.15 m
	Lemniscate†	10.22 m/s	155.32 s	480.67 m
Piloted	Ellipse‡	9.50 m/s	575.62 s	3355.67 m
	Lemniscate‡	8.93 m/s	**594.60 s**	**3577.65 m**

†Flown twice in 6 flights (3 brightness × 2 camera settings). ‡Flown as many times as possible in 6 flights (3 brightness × 2 camera settings).





Data Format

Raw data:
- Rosbags
- Single CSVs

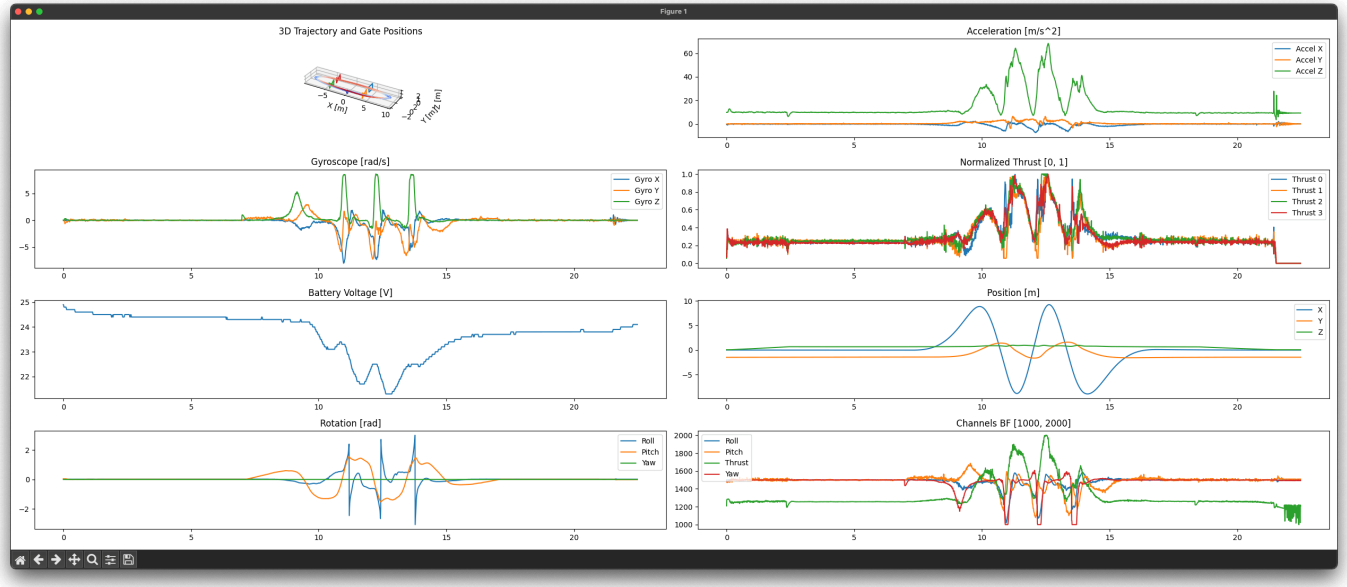
Interpolated data:
- comprehensive CSVs
  - Camera-aligned
  - Uniform-sampling

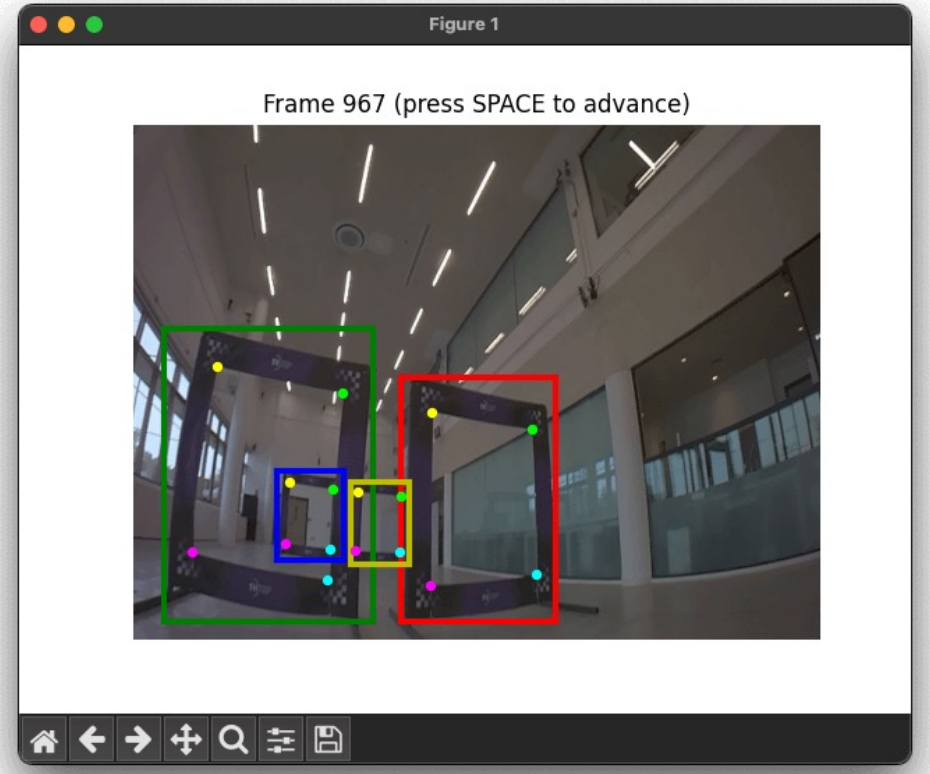
Images and Labels:
- JPEG
- TXT (0 c_x c_y w h tl_x tl_y tl_v tr_x tr_y tr_v br_x br_y br_v bl_x bl_y bl_v)

TABLE IV: Data available in the precompiled `cam_ts_sync.csv` and `500hz_freq_sync.csv` (Sec. V-A)

Column Number and Quantity Name	Unit	Data Type
0. elapsed_time	s	float
1. timestamp	μs	int
2. img_filename	n/a	string
3. accel_[x|y|z]	m/s^2	float
6. gyro_[x|y|z]	rad/s	float
9. thrust[0-3]	1	float $\in [0, 1]$
13. channels_[roll|pitch|thrust|yaw]	1	int $\in [1000, 2000]$
17. aux[1-4]	1	int $\in [1000, 2000]$
21. vbat	V	float
22. drone_[x|y|z]	m	float
25. drone_[roll|pitch|yaw]	rad	float
28. drone_velocity_linear_[x|y|z]	m/s^2	float
31. drone_velocity_angular_[x|y|z]	rad/s	float
34. drone_residual	m	float
35. drone_rot[[0-8]]	1	float
44. gate[1-4]_int_[x|y|z]	m	float
56. gate[1-4]_int_[roll|pitch|yaw]	rad	float
68. gate[1-4]_int_residual	m	float
72. gate[1-4]_int_rot[[0-8]]	1	float
108. gate[1-4]_marker[1-4]_[x|y|z]	m	float

Supporting Scripts





Additional Resources:

- camera_calibration
  - calibration_results.json — Camera parameters in JSON format.
  - calibration_results.npz — Camera parameters in NumPy format.
  - drone_to_camera.json — Translation from the drone center to the camera
- scripts
  - camera_calibration.py — Script used to generate the files in `camera_calibration/`.
  - create_std_bag.py. — Script used to generate standard ROS2 bags
  - data_interpolation.py — Script used to generate the comprehensive CSV files interpolated at arbitrary frequencies.
  - reference_controller.py — PID controller used for the autonomous flights.

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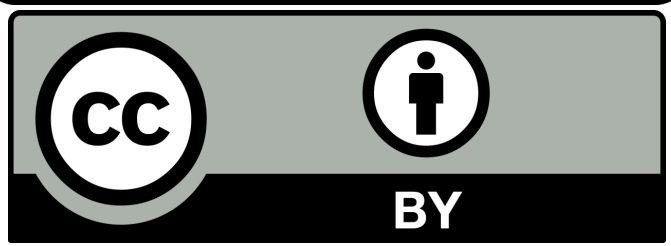
Thank You!

Pre-Print

GitHub



https://github.com/tii-racing/drone-racing-dataset