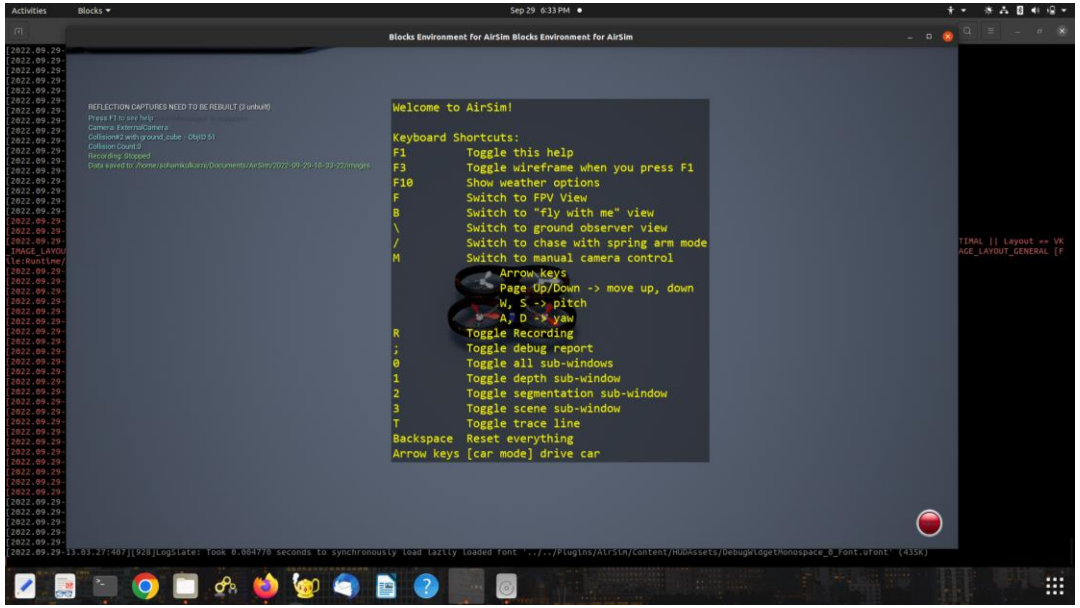
Review in project development #2

8th October 2022

AirSim

- Setup and installation for AirSim, Drone Racing Lab done

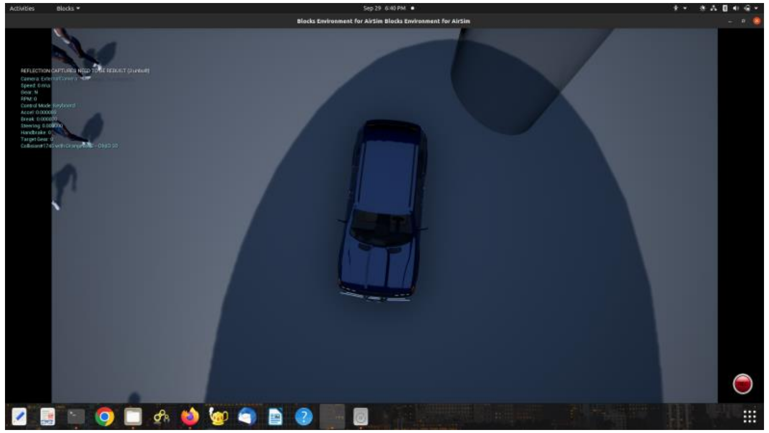


```
REFLECTION CAPTURES NEED TO BE REBUILT (3 unbuilt)
Press F1 to see help
Camera: ExternalCamera
Collision#2 with ground_cube - ObjID 51
Collision Count:0
Recording: Stopped
Data saved to: /home/sohamkulkarni/Documents/AirSim/2022-09-29-18-33-22/images
```

```
Welcome to AirSim!

Keyboard Shortcuts:
F1         Toggle this help
F3         Toggle wireframe when you press F1
F10        Show weather options
F          Switch to FPV View
B          Switch to "fly with me" view
\          Switch to ground observer view
/          Switch to chase with spring arm mode
M          Switch to manual camera control
              Arrow keys
              Page Up/Down -> move up, down
              W, S -> pitch
              A, D -> yaw
R          Toggle Recording
;          Toggle debug report
0          Toggle all sub-windows
1          Toggle depth sub-window
2          Toggle segmentation sub-window
3          Toggle scene sub-window
T          Toggle trace line
Backspace  Reset everything
Arrow keys [car mode] drive car
```

```
[2022.09.29-13.03.27:407][928]LogSlate: Took 0.004770 seconds to synchronously load lazily loaded font '../../Plugins/AirSim/Content/HUDAssets/DebugWidgetMonospace_0_Font.ufont' (435K)
```



AirSim API and baselines

- Tried out different environment configurations, waypoints based navigation in the AirSim python API

Some baseline methods available are:

- Learning Visuomotor Policies for Aerial Navigation Using Cross-Modal Representations
- Representation Learning for Event-based Visuomotor Policies

- Available at: https://www.microsoft.com/en-us/research/group/autonomous-systems-group-robotics/publications/

AirSim Experiments

- Experiments tried out: Stereo matching and Obstacle Detection
- RL: DQN, PPO
- Holistic Parameters: # of people, speed (max)
- Policy: Stop and wait whenever there's obstacles within 0.2 m.
- The reward is defined as:

----moving forward in x direction: +1 x (V_x)
----Deviation in y direction: -1 x |y|
----Collision: -5

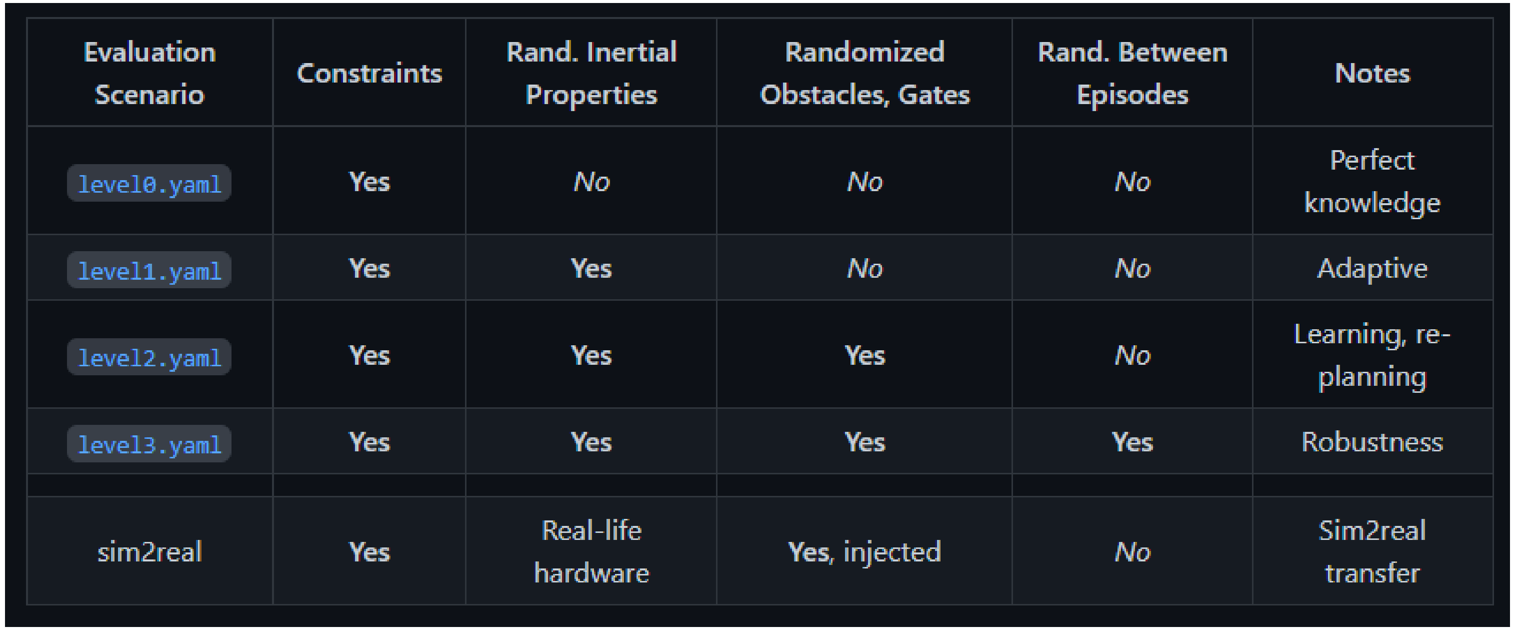
- Safe flight distance = 46.1 m (at slow speeds)

Safe Robot Learning

- The task is to design a controller/planner that enables a quadrotor (*Crazyflie 2.x*) to **safely fly through a set of gates and reach a predefined target despite uncertainties in the robot dynamics (e.g., mass and inertia) and the environment (e.g., wind and position of the gates)**. The algorithms will be evaluated regarding their safety (e.g., no collisions) and performance (e.g., time to target). We encourage participants to explore both control and reinforcement learning approaches (e.g., robust, adaptive, predictive, learning-based and optimal control, and model-based/model-free reinforcement learning). The controller/planner has access to the position and attitude measurements provided by a motion capture system and the noisy pose of the closest next gate. The controller can send position, velocity, acceleration and heading references to an onboard position controller.

Safe Robot Learning

- Evaluation scenarios:

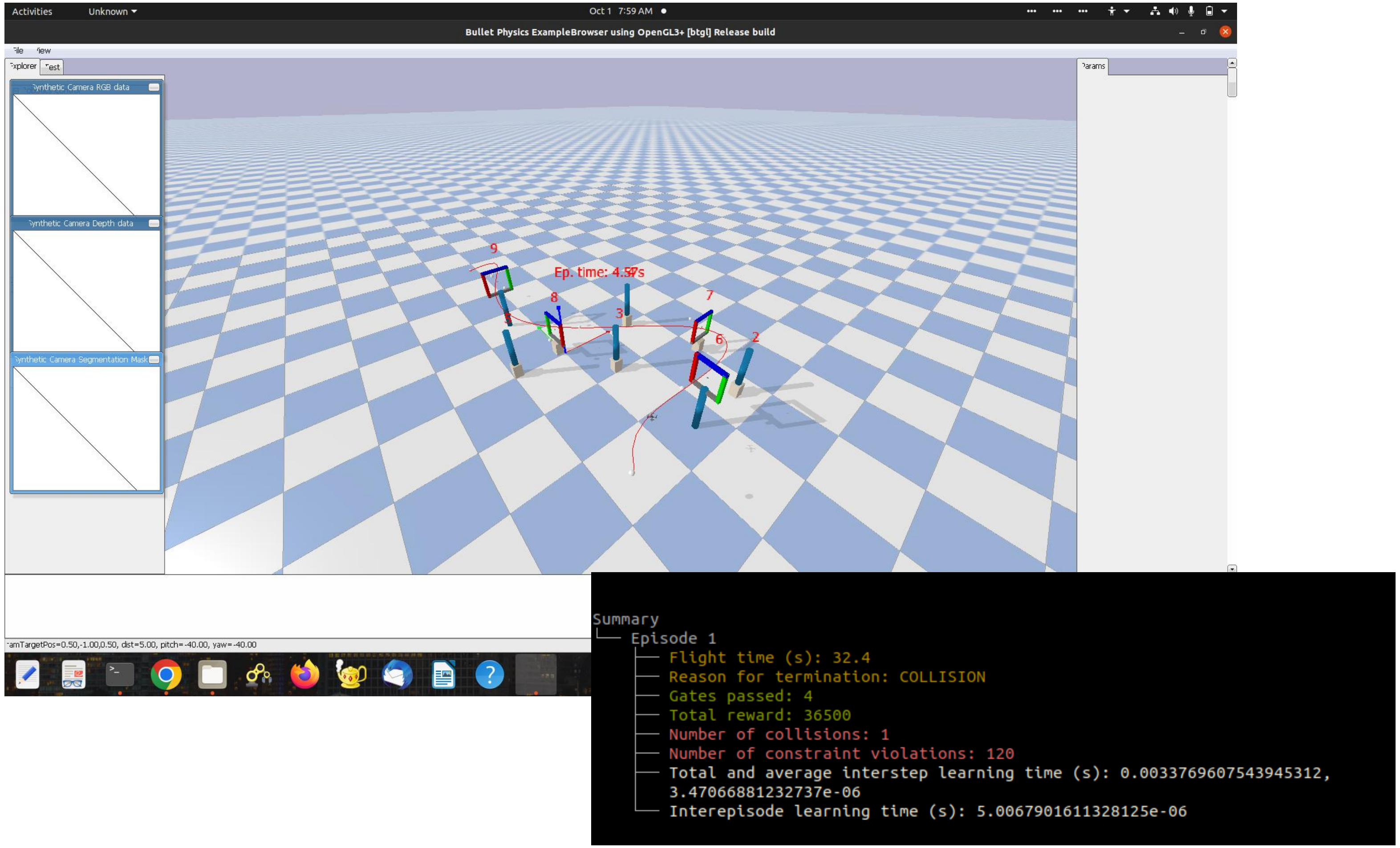


Evaluation Scenario	Constraints	Rand. Inertial Properties	Randomized Obstacles, Gates	Rand. Between Episodes	Notes
`level0.yaml`	**Yes**	*No*	*No*	*No*	Perfect knowledge
`level1.yaml`	**Yes**	**Yes**	*No*	*No*	Adaptive
`level2.yaml`	**Yes**	**Yes**	**Yes**	*No*	Learning, re-planning
`level3.yaml`	**Yes**	**Yes**	**Yes**	**Yes**	Robustness
sim2real	**Yes**	Real-life hardware	**Yes**, injected	*No*	Sim2real transfer

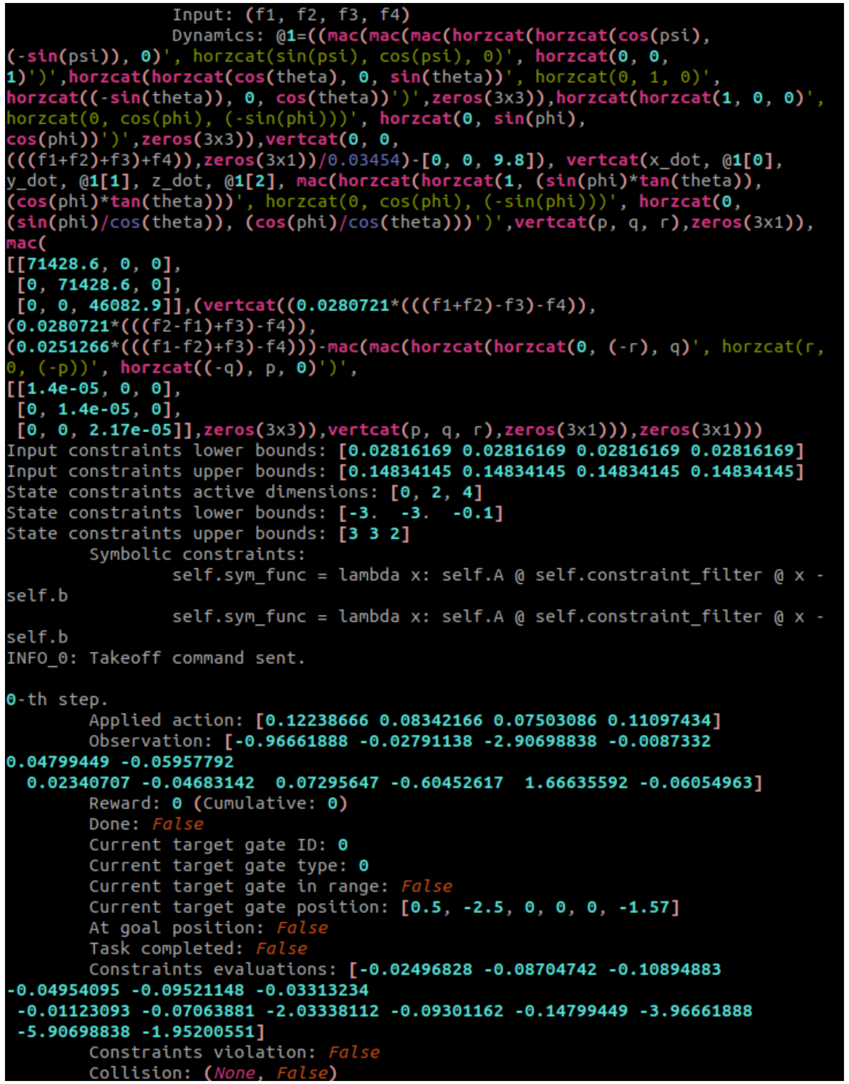
- Testing in Level 0 is done, presently working for Level 1.

Safe Robot Learning

- Simulation results:


Activities
Unknown
Oct 1 7:59 AM
Bullet Physics ExampleBrowser using OpenGL3+ [btgl] Release build
ile
iew
xplorer
est
arams
ynthetic Camera RGB data
ynthetic Camera Depth data
ynthetic Camera Segmentation Mask
Ep. time: 4.57s
9
8
3
7
5
6
2
amTargetPos=0.50,-1.00,0.50, dist=5.00, pitch=-40.00, yaw=-40.00

```
Summary
└── Episode 1
    ├── Flight time (s): 32.4
    ├── Reason for termination: COLLISION
    ├── Gates passed: 4
    ├── Total reward: 36500
    ├── Number of collisions: 1
    ├── Number of constraint violations: 120
    ├── Total and average interstep learning time (s): 0.0033769607543945312,
    │   3.47066881232737e-06
    └── Interepisode learning time (s): 5.0067901611328125e-06
```



```
                Input: (f1, f2, f3, f4)
                Dynamics: @1=((mac(mac(mac(horzcat(horzcat(cos(psi),
(-sin(psi)), 0)', horzcat(sin(psi), cos(psi), 0)', horzcat(0, 0,
1)')',horzcat(horzcat(cos(theta), 0, sin(theta))', horzcat(0, 1, 0)',
horzcat((-sin(theta)), 0, cos(theta))')',zeros(3x3)),horzcat(horzcat(1, 0, 0)',
horzcat(0, cos(phi), (-sin(phi)))', horzcat(0, sin(phi),
cos(phi))')',zeros(3x3)),vertcat(0, 0,
(((f1+f2)+f3)+f4)),zeros(3x1))/0.03454)-[0, 0, 9.8]), vertcat(x_dot, @1[0],
y_dot, @1[1], z_dot, @1[2], mac(horzcat(horzcat(1, (sin(phi)*tan(theta)),
(cos(phi)*tan(theta)))', horzcat(0, cos(phi), (-sin(phi)))', horzcat(0,
(sin(phi)/cos(theta)), (cos(phi)/cos(theta)))')',vertcat(p, q, r),zeros(3x1)),
mac(
[[71428.6, 0, 0],
 [0, 71428.6, 0],
 [0, 0, 46082.9]],(vertcat((0.0280721*(((f1+f2)-f3)-f4)),
(0.0280721*(((f2-f1)+f3)-f4)),
(0.0251266*(((f1-f2)+f3)-f4)))-mac(mac(horzcat(horzcat(0, (-r), q)', horzcat(r,
0, (-p))', horzcat((-q), p, 0)')',
[[1.4e-05, 0, 0],
 [0, 1.4e-05, 0],
 [0, 0, 2.17e-05]],zeros(3x3)),vertcat(p, q, r),zeros(3x1))),zeros(3x1)))
Input constraints lower bounds: [0.02816169 0.02816169 0.02816169 0.02816169]
Input constraints upper bounds: [0.14834145 0.14834145 0.14834145 0.14834145]
State constraints active dimensions: [0, 2, 4]
State constraints lower bounds: [-3.  -3.  -0.1]
State constraints upper bounds: [3 3 2]
        Symbolic constraints:
                self.sym_func = lambda x: self.A @ self.constraint_filter @ x -
self.b
                self.sym_func = lambda x: self.A @ self.constraint_filter @ x -
self.b
INFO_0: Takeoff command sent.

0-th step.
        Applied action: [0.12238666 0.08342166 0.07503086 0.11097434]
        Observation: [-0.96661888 -0.02791138 -2.90698838 -0.0087332
0.04799449 -0.05957792
  0.02340707 -0.04683142  0.07295647 -0.60452617  1.66635592 -0.06054963]
        Reward: 0 (Cumulative: 0)
        Done: False
        Current target gate ID: 0
        Current target gate type: 0
        Current target gate in range: False
        Current target gate position: [0.5, -2.5, 0, 0, 0, -1.57]
        At goal position: False
        Task completed: False
        Constraints evaluations: [-0.02496828 -0.08704742 -0.10894883
-0.04954095 -0.09521148 -0.03313234
 -0.01123093 -0.07063881 -2.03338112 -0.09301162 -0.14799449 -3.96661888
 -5.90698838 -1.95200551]
        Constraints violation: False
        Collision: (None, False)
```

Safe Robot Learning

- *Tested Controllers (for basic trajectory tracking):*
- LQR
- iLQR
- Linear MPC
- GP-MPC
- SAC
- PPO
- DDPG
- Safety Layer
- RARL
- RAP
- MPSC
- CBF