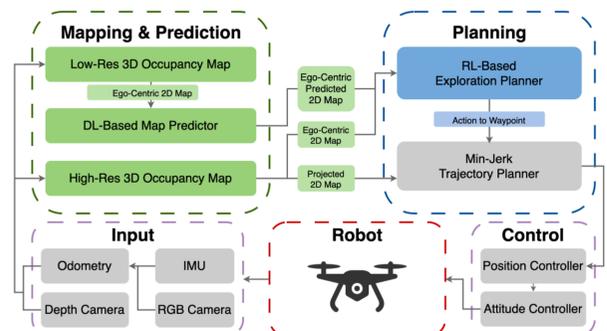


### MOTIVATION

- Autonomous exploration has many direct real-world applications
- Learn to explore instead of model-based approach
- Deploy on SWaP constrained MAVs

### PROPOSED SYSTEM



- A mapping & DL-based prediction module that construct occupancy maps and predict occupancy information for efficient exploration
- A DRL-based planning module that leverages the prediction and observations to select exploration actions that gather informative observations

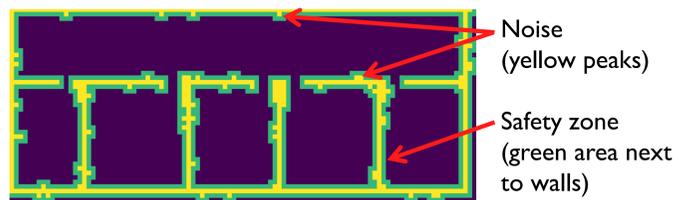
### HARDWARE PLATFORM

Pixhawk 4 Mini	Intel NUC 10
Intel RealSense D435i	ModalAI VOXL
Flight time ~6 mins	
Weight ~1.3kg	
3S 5200mAh Li-Po	

### METHODOLOGY

#### Training Samples

- 50,000 synthetic examples
- Floor maps include doors and cabinets
- Furniture below 1.5M are ignored

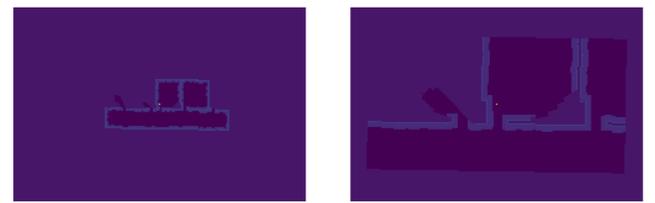


#### Action Modeling

- 0 – stay put, 1 – turn right, 2 – turn left, 3 – move forward, 4 – turn right and move forward, 5 – turn left and move forward

#### Observation Space

- Last action (to handle drone's dynamics)
- Building map in two resolutions



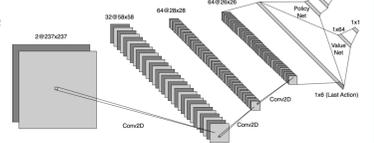
#### Occupancy Predictor

- Standard convolutional Encoder-Decoder:
  - 21 Encoding + 21 Decoding layers
  - Skip connections between each
- Dynamic thresholding during exploration
- $F_1 > 0.92$  with 98% coverage



#### RL Planner

- Standard CNN for feature extraction
- Additional fully connected layers (separate for actor and critic)



#### Reward

- Reward based on prediction
- $\mathcal{R}(t) = -1 + \begin{cases} -l & \text{if collision} \\ r(t) & \text{otherwise} \end{cases}$
- $r(t) = w \cdot [F_1(t+1) - F_1(t)]$
- $F_1 = TP / [TP + 0.5(N_M - T)]$ 
  - $TP$  – Number of correctly predicted occupied cells
  - $N_M$  – Number of interior cells
  - $T$  – Total number of correctly predicted cells

#### Training

- Train in two phases:
  - Without prediction
  - Gradually add predicted information

### RESULTS

#### Simulation Experiments

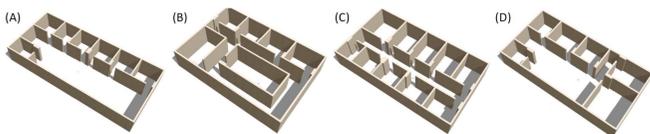
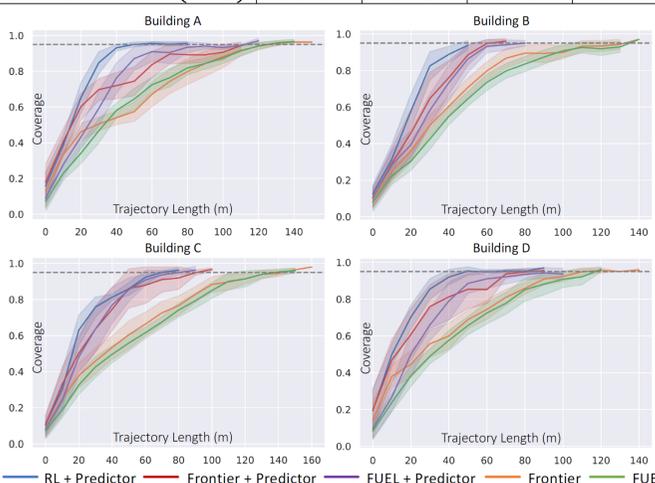


Table 1: Averaged mapping path length (m) in Gazebo

Method	(A)	(B)	(C)	(D)
Frontier	125.0	108.8	132.7	110.0
FUEL	123.6	122.0	128.6	106.0
Frontier + Predictor	83.0	60.4	69.2	63.0
FUEL + Predictor	77.3	64.7	74.7	67.8
DRL + Predictor (ours)	50.2	49.3	66.3	47.4

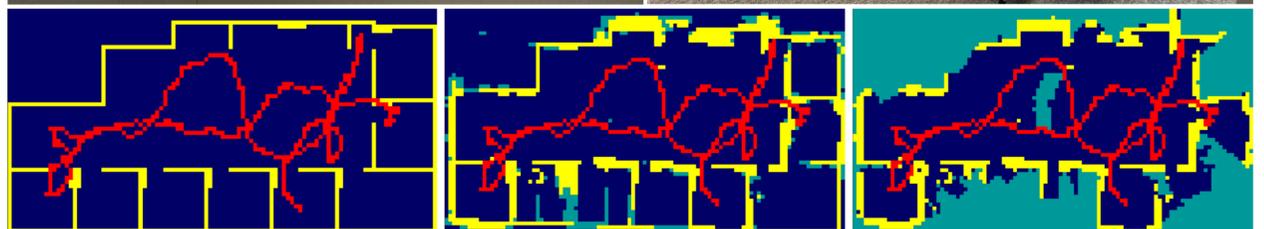


#### Computation Experiments



- CPU Utilization 32.7% in total
- 4 TOP Coral TPU: Predictor 150ms; Planner 8ms

#### Real-World Experiments



The proposed method achieves a 50-60% shorter overall path length compared to the classic and the state-of-the-art methods

Scan QR for more details

