End-to-End Learning for Fighting Forest Fires (EELFFF)

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Motivation

- Forest wildfires cause loss of life and significant economic and property damage
- Wildfires are an attractive domain for autonomous robotic systems
- Centralized systems can be prohibitively complex and prone to a single point of failure
- Goal: **cooperative** and **decentralized** system that scales independent of forest size and number of agents

Problem Statement

- Discrete grid, probabilistic wildfire model[1]
- Each tree state: healthy, burning, or burnt
- Quadrotor agents:
  - Camera – observes 16 x 16 image of forest
  - Sonar sensor - detects closest agent (x, y)
  - Notified of ignition point (x, y)
  - Apply fire retardant along path
- Agent path parameterized by 6 waypoints q
- Train a single neural network offline to generate paths online for each agent

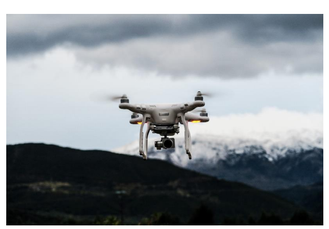


Figure 1. quadrotor agent [source: http://bit.ly/2rHb7Ud]

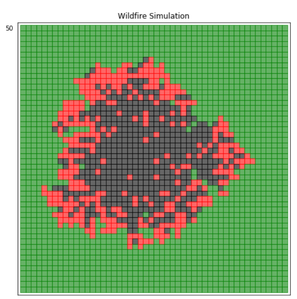
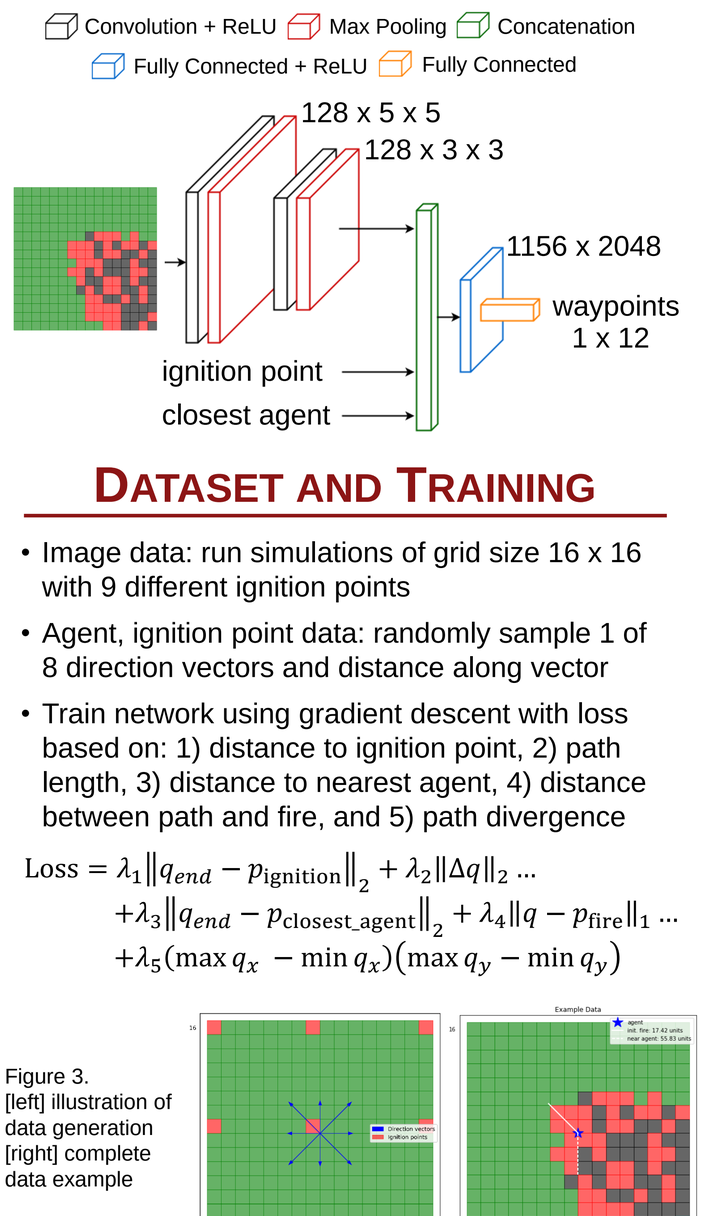


Figure 2. Example simulation for 50 x 50 size forest

Network Architecture



Dataset and Training

- Image data: run simulations of grid size 16 x 16 with 9 different ignition points
- Agent, ignition point data: randomly sample 1 of 8 direction vectors and distance along vector
- Train network using gradient descent with loss based on: 1) distance to ignition point, 2) path length, 3) distance to nearest agent, 4) distance between path and fire, and 5) path divergence

$$\text{Loss} = \lambda_1 \left\| q_{end} - p_{\text{ignition}} \right\|_2 + \lambda_2 \|\Delta q\|_2 \ldots$$
$$+\lambda_3 \left\| q_{end} - p_{\text{closest\_agent}} \right\|_2 + \lambda_4 \|q - p_{\text{fire}}\|_1 \ldots$$
$$+\lambda_5 (\max q_x - \min q_x)(\max q_y - \min q_y)$$

Figure 3. [left] illustration of data generation [right] complete data example

Results

- Performance metric: $\frac{\text{number of trees burnt}}{\text{total number of trees}}$
- Currently, generated a trained network and tested several baseline methods

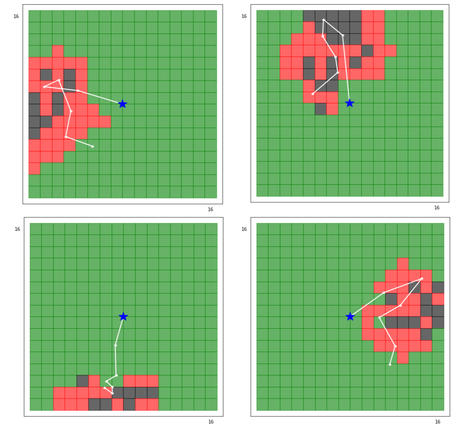
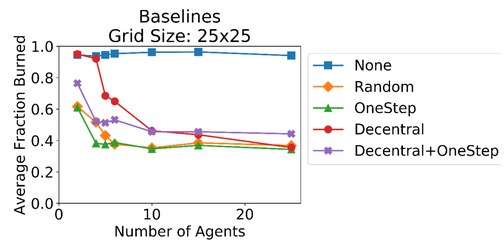


Figure 4. Example trajectories generated by the trained network

Figure 5. Performance of two centralized and decentralized heuristic methods



Conclusions

- Agents identify fires and try to cover as many as possible
- Network can be run online
- Agents show some level of cooperation
- Future work: test the entire integrated system

References: [1] A. Somanath, S. karaman, and K. Youcef-Toumi, "Controlling stochastic growth processes on lattices: Wildfire management with robotic fire extinguishers," in 53rd IEEE Conference on Decision and Control. IEEE, 2014, pp. 1432-1327