“Tiny Robot Learning for Source Seeking on a Nano Quadcopter”

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Introduction

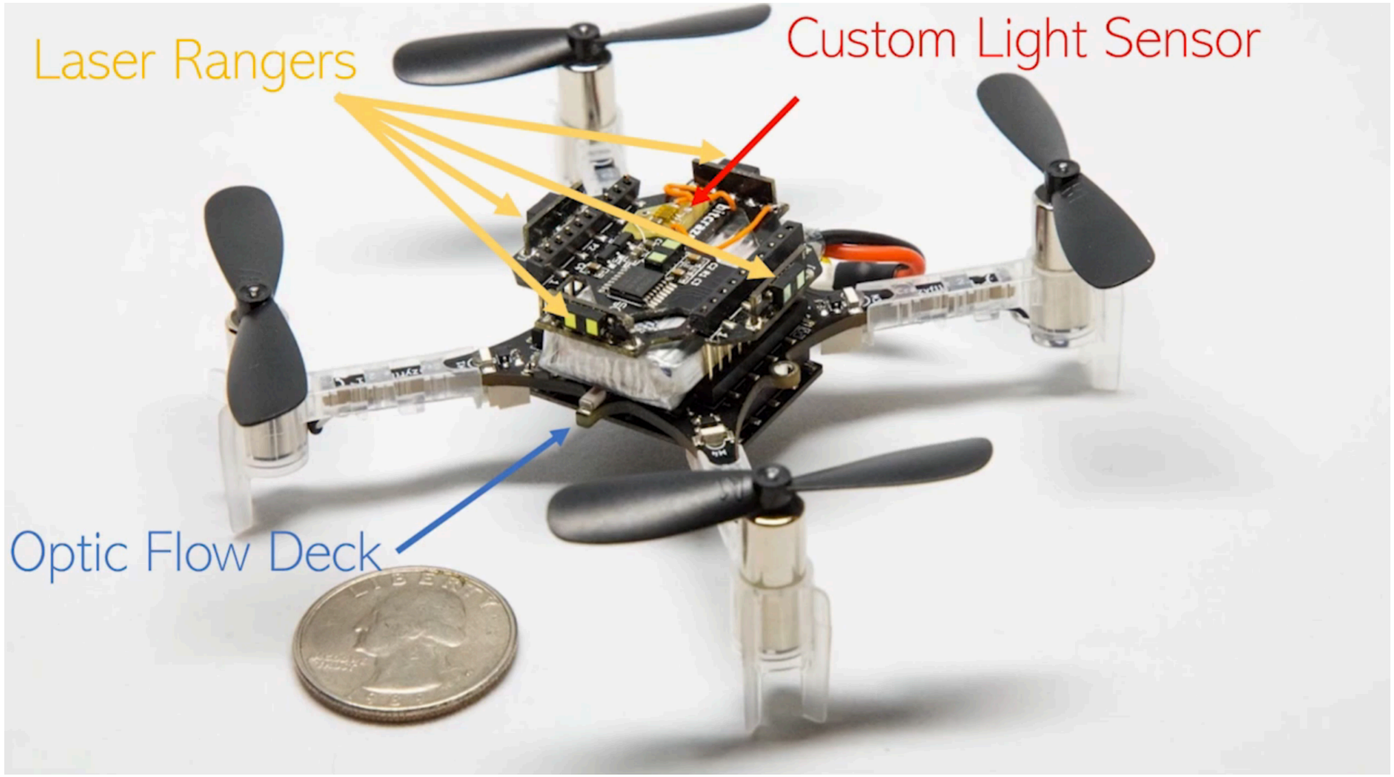
Source Seeking

- Definition: autonomously navigate towards a specific target or source based on sensor feedback
- Applications
  - Save and rescue
  - Military
  - Surveillance
- How can a drone navigate in real world environments without collision?

Background

Hardware Components

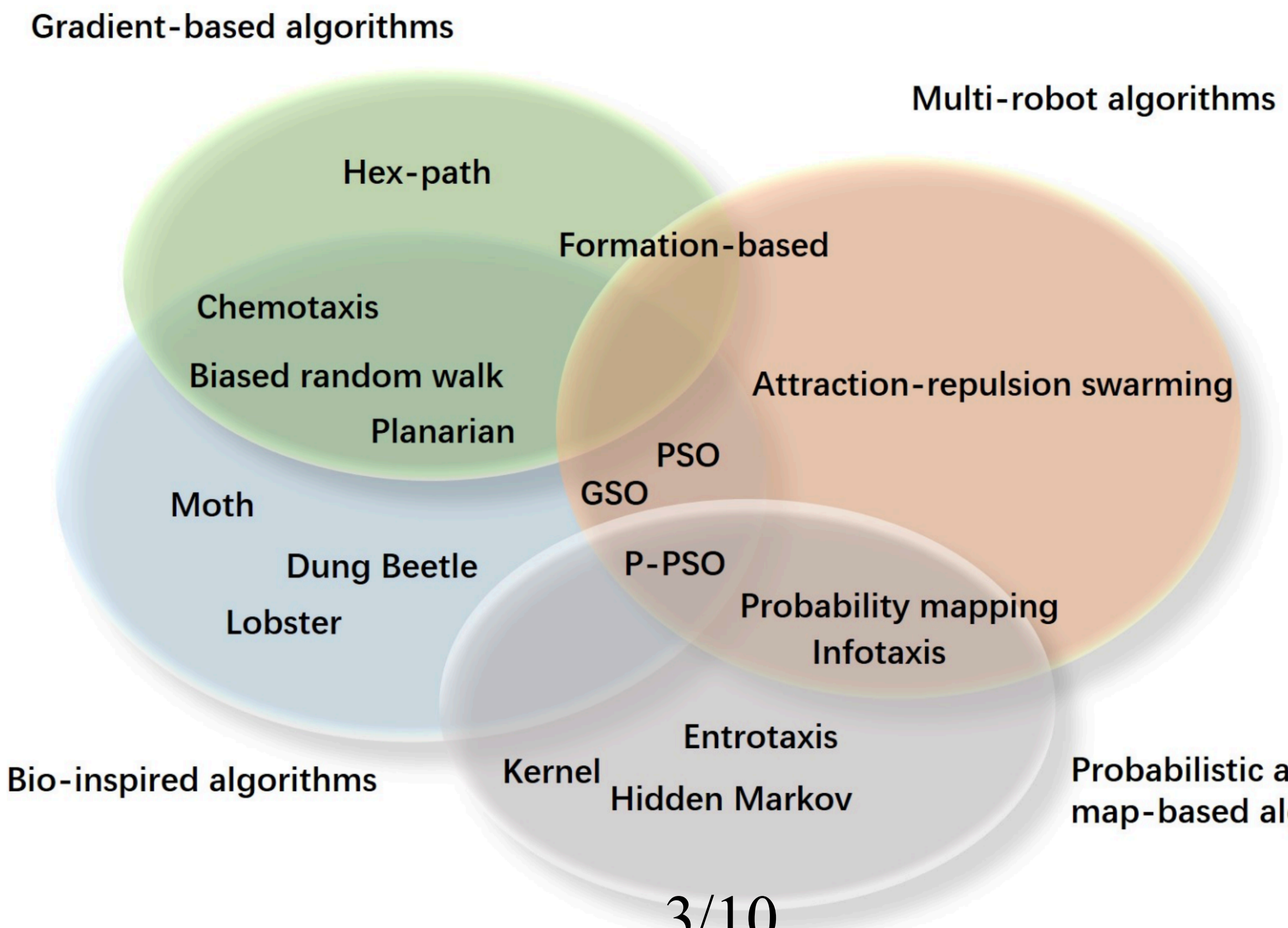
- BitCraze CrazyFlie
  - Nano quadcopter
  - Size: 9.2 cm x 9.2 cm
  - Weight: 27g
  - Max payload: 15g
  - Flight time: 7 min
- ARM Cortex-M4
  - 32-bit RISC ARM processor
  - Light and low power
- Sensors
  - 4 laser rangers with 5m range
  - TSL2591 light sensor



Background (Cont.)

Source Seeking Algorithms

Unstable



Requires GPS

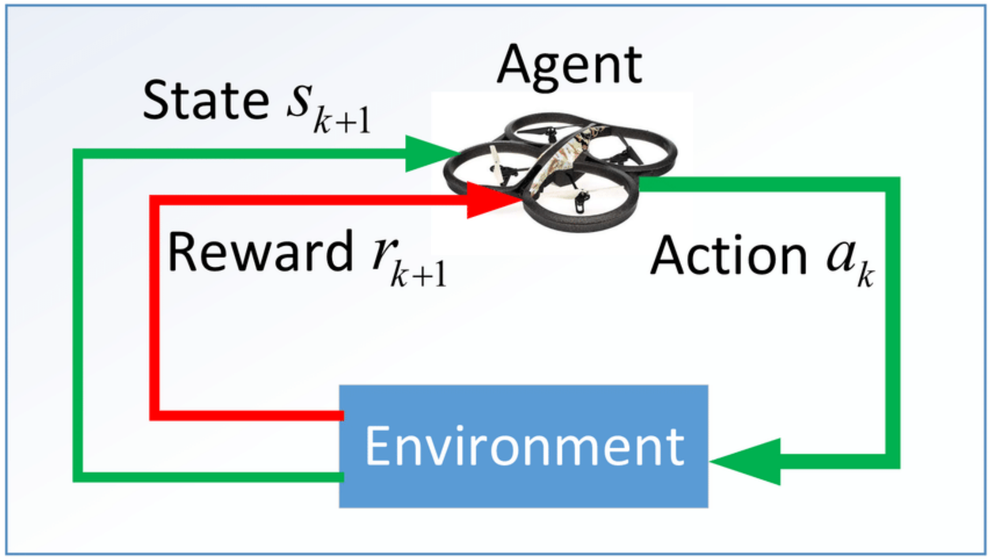
High energy consumption

High computational cost and memory

Reinforcement Learning

Learning Via Trial & Error

- RL is a kind of machine learning
- Used in chess bots, robots, etc…
- trains agents by giving negative or positive rewards
- Reaching goal —> Positive
- Colliding —> Negative

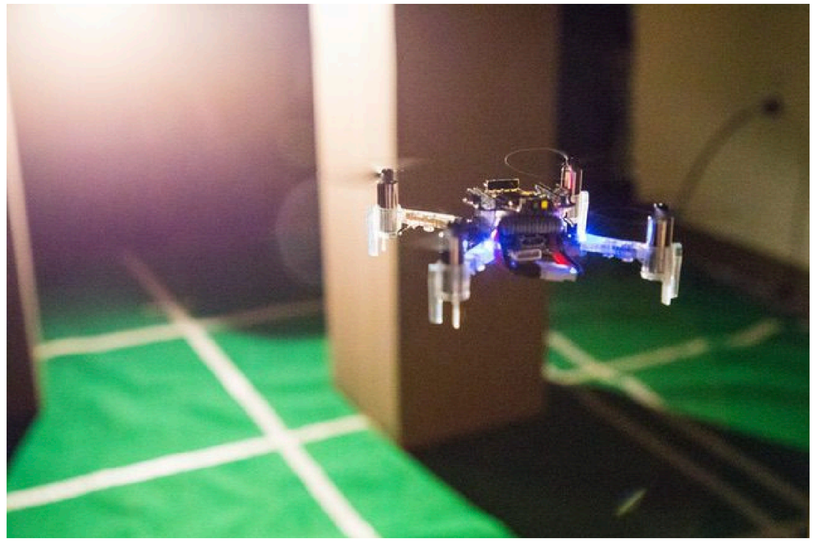


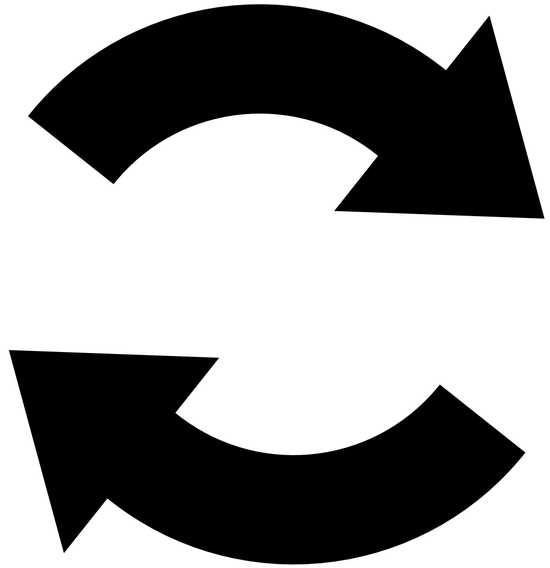
Reinforcement Learning (Cont.)

States, actions & rewards

$$\mathbf{o} = (l_1, l_2, l_3, l_4, s_1, s_2)$$

$$r = 1000 \cdot \alpha - 100 \cdot \beta$$

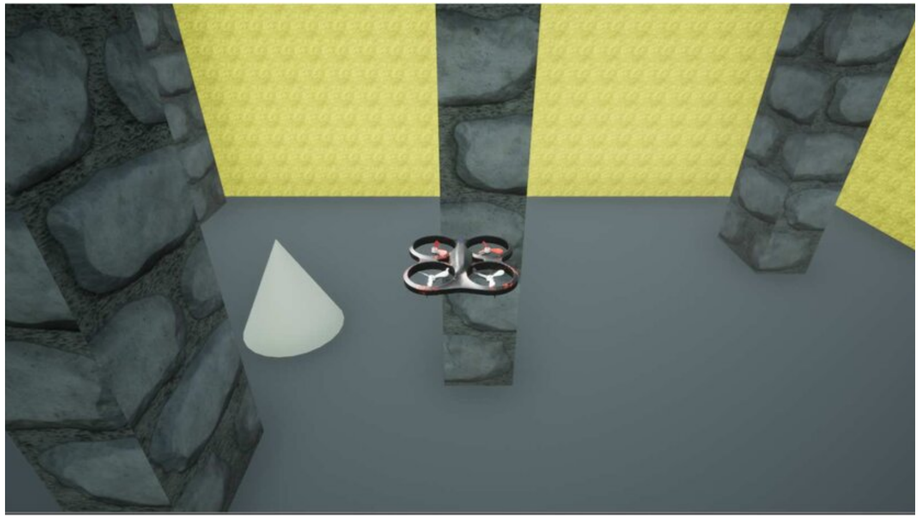


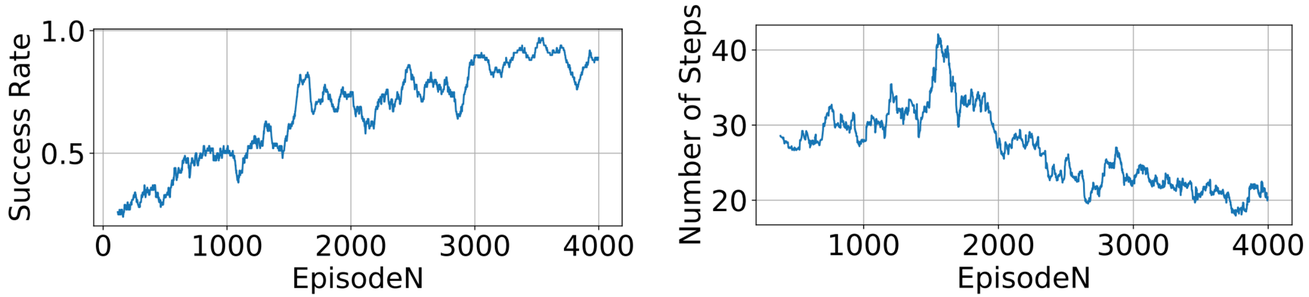


$$\mathbf{a} = \left(v_x, \dot{\psi}\right)^3$$

Simulation Environment

- Real world training is expensive and time consuming
- Simulations allow for exhilarated learning
- “Air Learning environment”





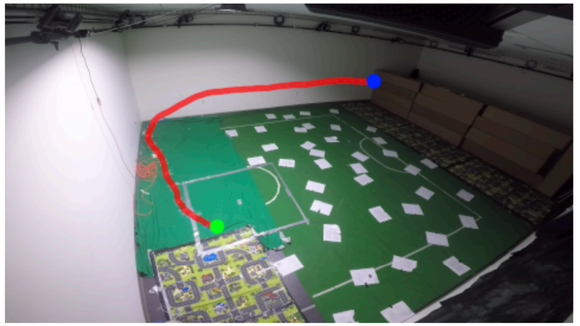
(a) Training success rates.

(b) Steps to locate source.

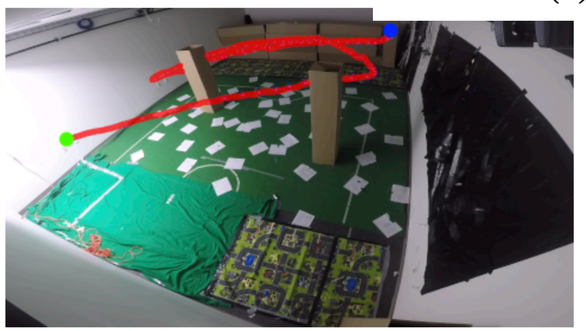
Fig. 6. Quality metrics during training.

Real World Environment

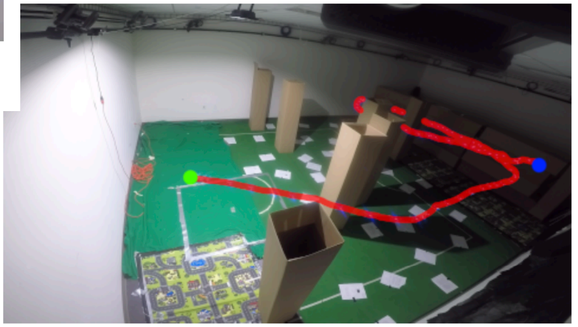
- The drone was tested in a 5x5m room
- 50W light source attached to the roof, radiating a 120 deg beam onto the ground, as the light source
- Drone flys at 1m/s
- 114 flight tests were conducted
- Three distinct obstacle densities: ‘NO OBS’, ‘LOW OBS’, and ‘HIGH OBS’



(b) 0 obstacles.



(c) 3 obstacles.



(d) 7 obstacles.

Extreme RAM Limitations

- 196 kB of RAM available on the Cortex-M4 microcontroller
- 131 kB is available for static allocation at compile time
- Bitcraze software stack uses 98 kB
- source seeking stack takes up 20.5 kB
- Neural network: two hidden layers of 20 nodes each

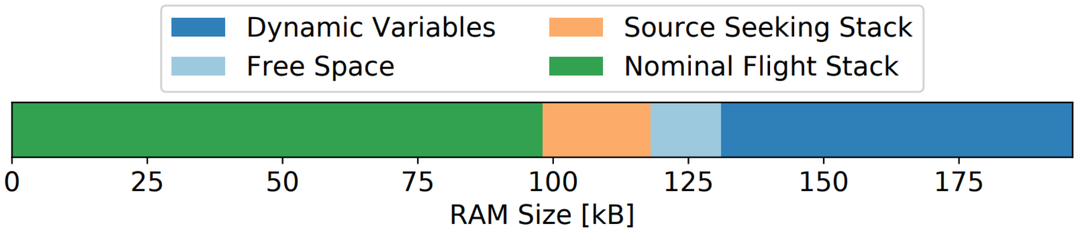


Fig. 4. RAM usage on the Bitcraze CrazyFlie, using a custom float inference stack. Total free space: 12.5 kB

Results

The Superiority of Machine Learning

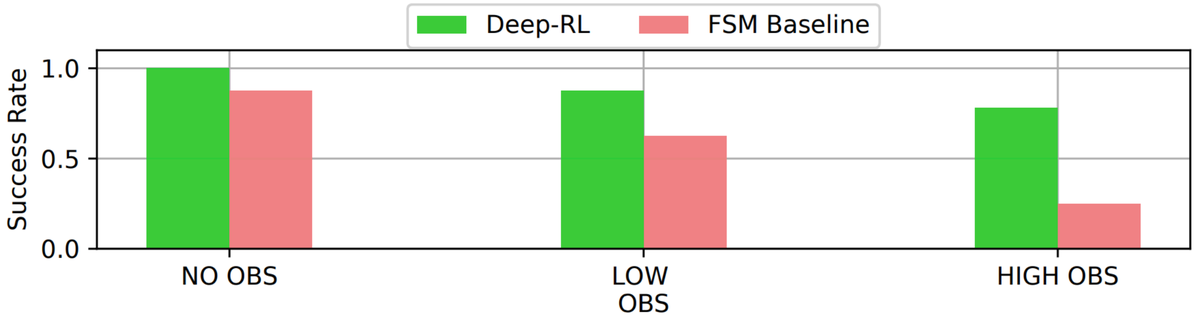


Fig. 9. Success rate over 104 flight experiments, comparing our deep reinforcement learning approach with the FSM baseline. Our solution consistently performs better, especially in high-density obstacle environments.

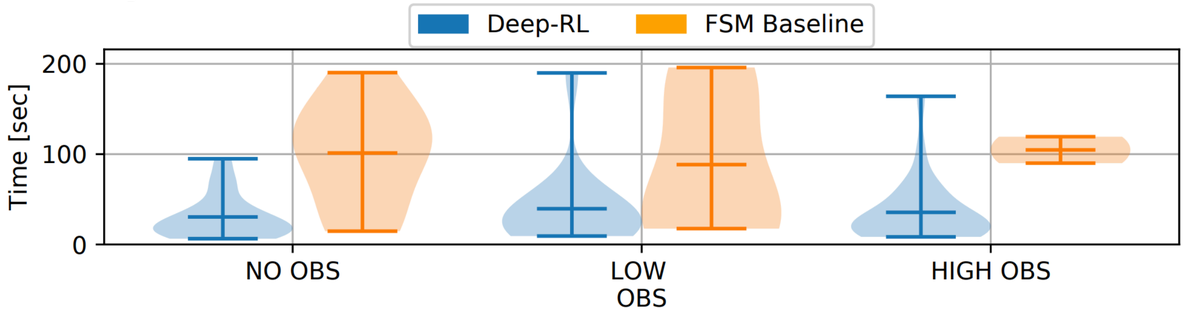


Fig. 11. Mission time in success over 104 flight experiments, comparing our deep RL approach with the FSM baseline.

Conclusion

- Deep reinforcement learning can be used as an effective source seeking algorithm
- Robust to the noise present in the real world
- Generalizes outside of the simulation environment
- Future work can consist of equipping more sensors and testing in outside environments

The End

Thanks For Your Attention

Paper Link: https://arxiv.org/pdf/1909.11236