Achieving Autonomous Drone Flight via a Hopfield Network Computer Vision System

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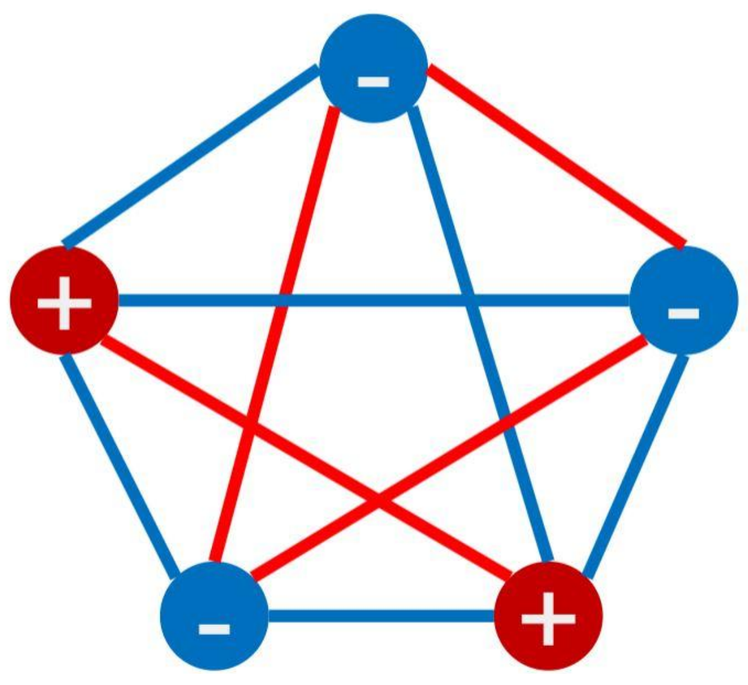
Background & Motivation

Hopfield Network (HNN):

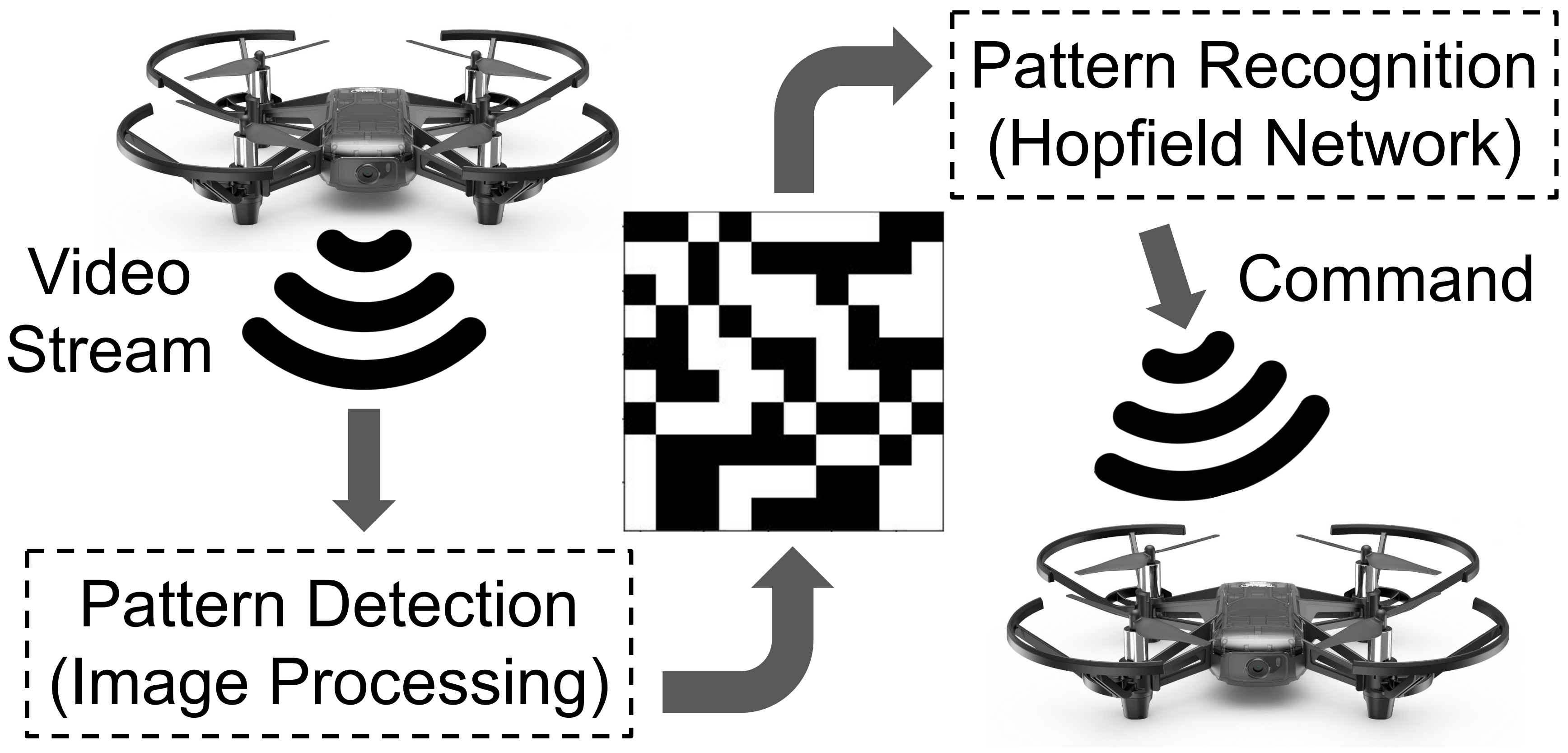
- Connected and symmetric recurrent neural network.
- All neurons impact the output with weighted connections.
- Patterns can be imprinted for optimization and associative memory.



Motivation:

- State-of-the-art computer vision models are computationally expensive, especially for real-time.
- HNNs are relatively cheaper and robust.
- Special hardware (GPUs/chips) are not needed.

Workflow

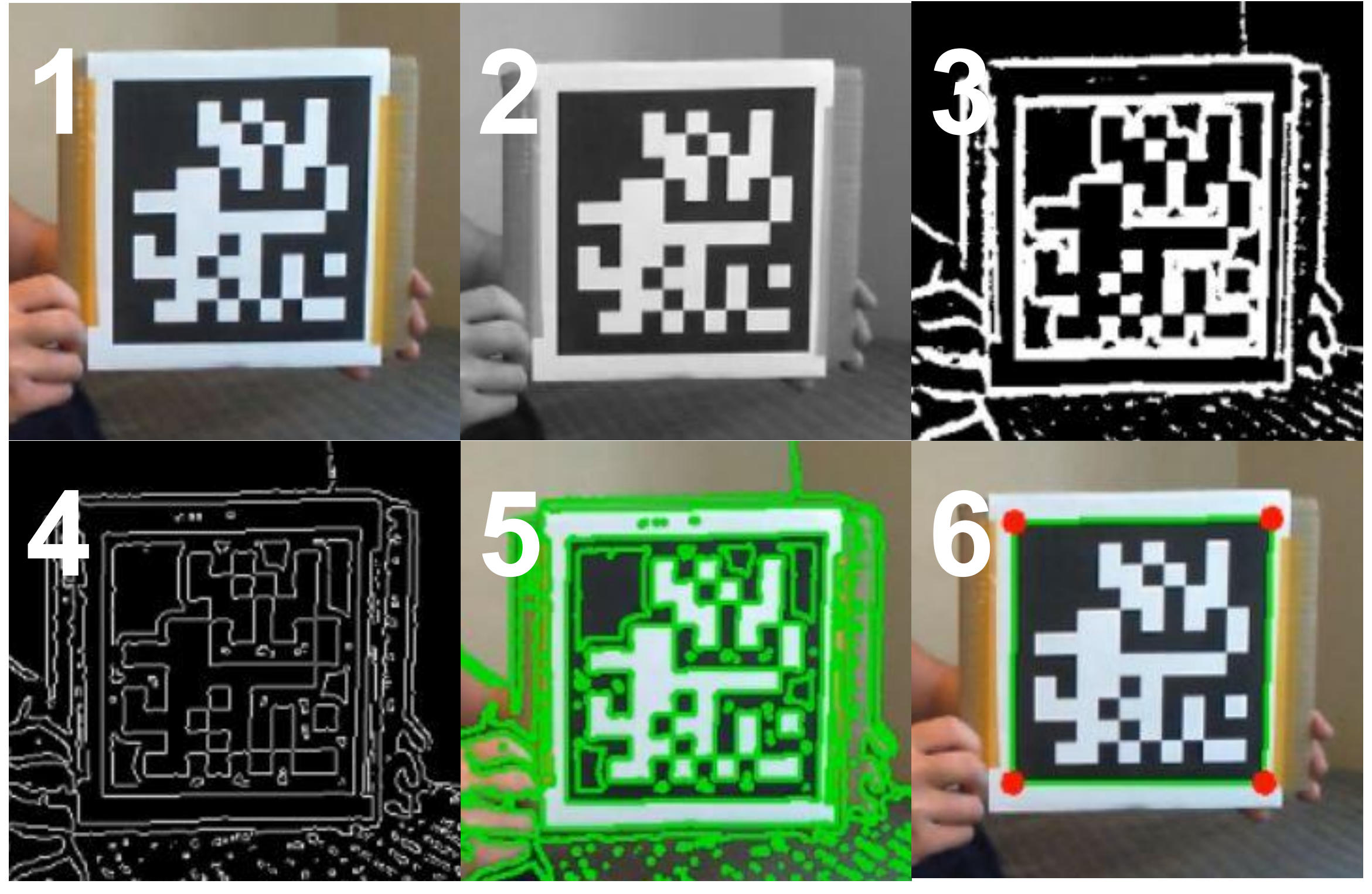

Video Stream
Pattern Detection (Image Processing)
Pattern Recognition (Hopfield Network)
Command

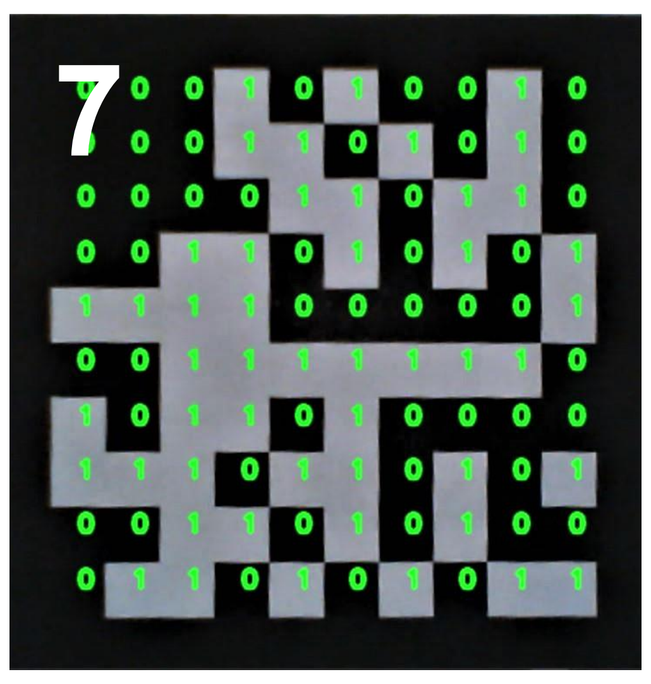
Pattern Detection (Image Processing)

- Algorithm is written in Python with OpenCV.

Detecting a Pattern:

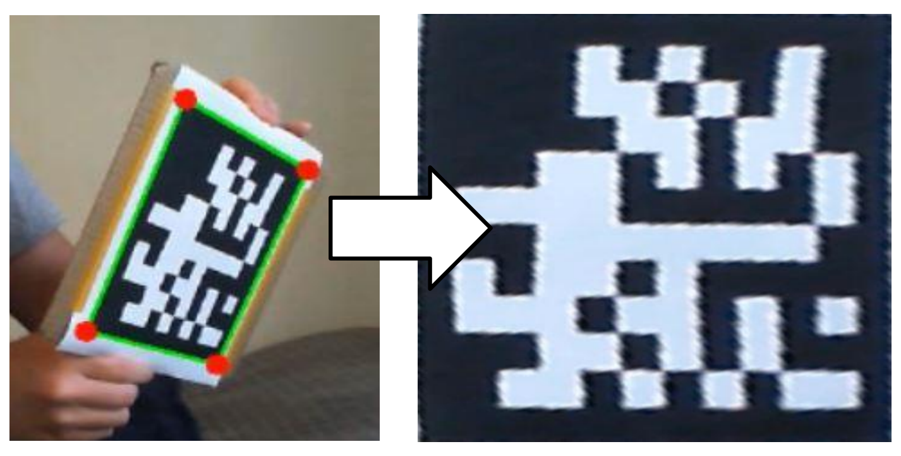
- Remove color for binary thresholding later (**Fig 2**).
- Apply adaptive threshold, ignoring lighting (**Fig 3**).
- Use Canny edge detection on the pattern (**Fig 4**).
- Find contours to make edges a points array (**Fig 5**).
- Detect pattern as a contour with four corners with several contours inside of it (**Fig 6**).
- Apply perspective transform (**Fig 8**), associate each pattern unit as 0 or 1 based on color value (**Fig 7**).



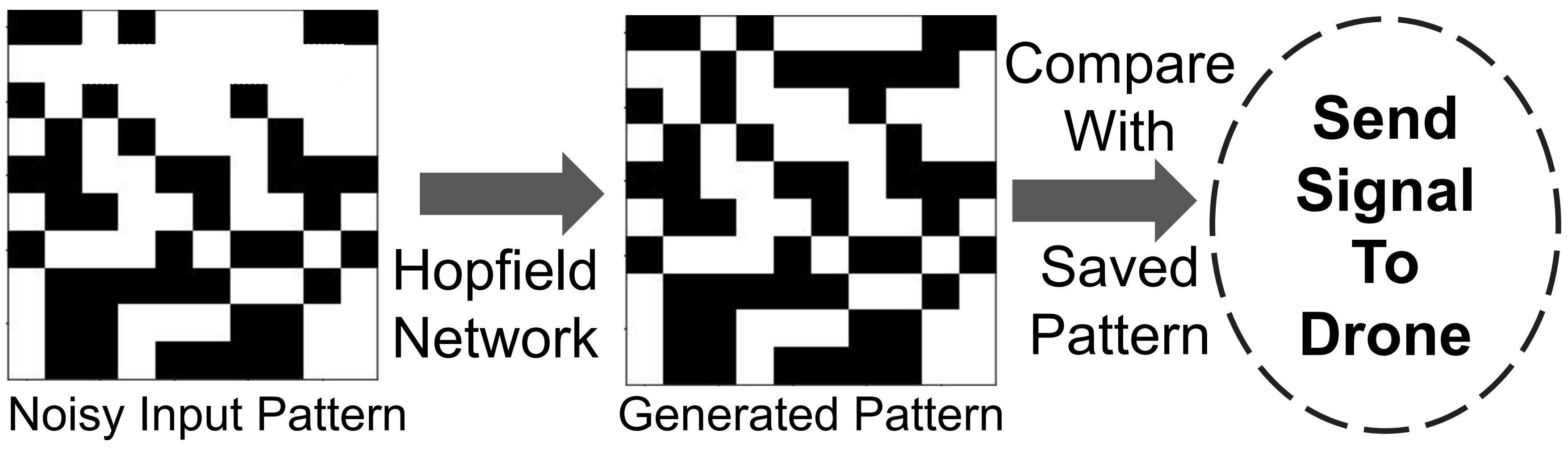


Perspective Transformation:

- Detect regardless of the pattern's orientation (**Fig 8**).



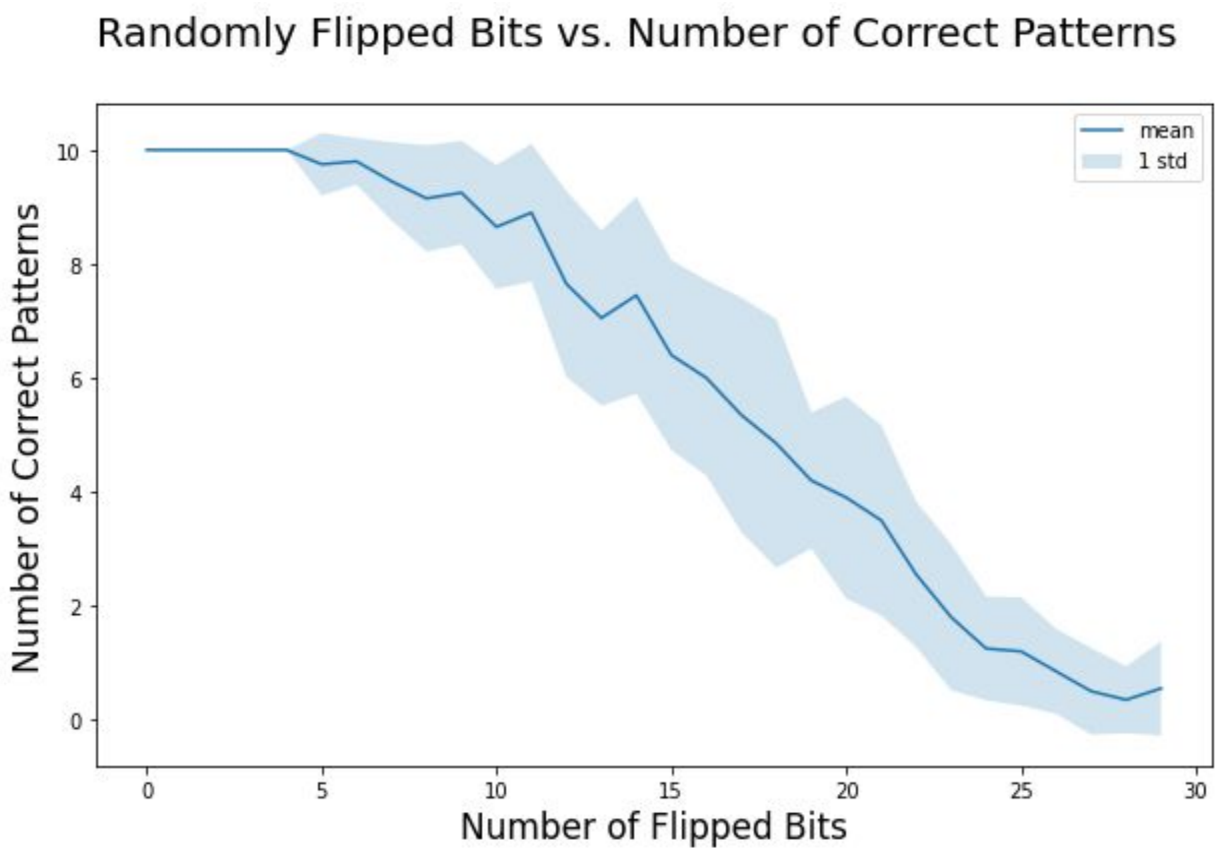
Pattern Recognition (Hopfield Network)

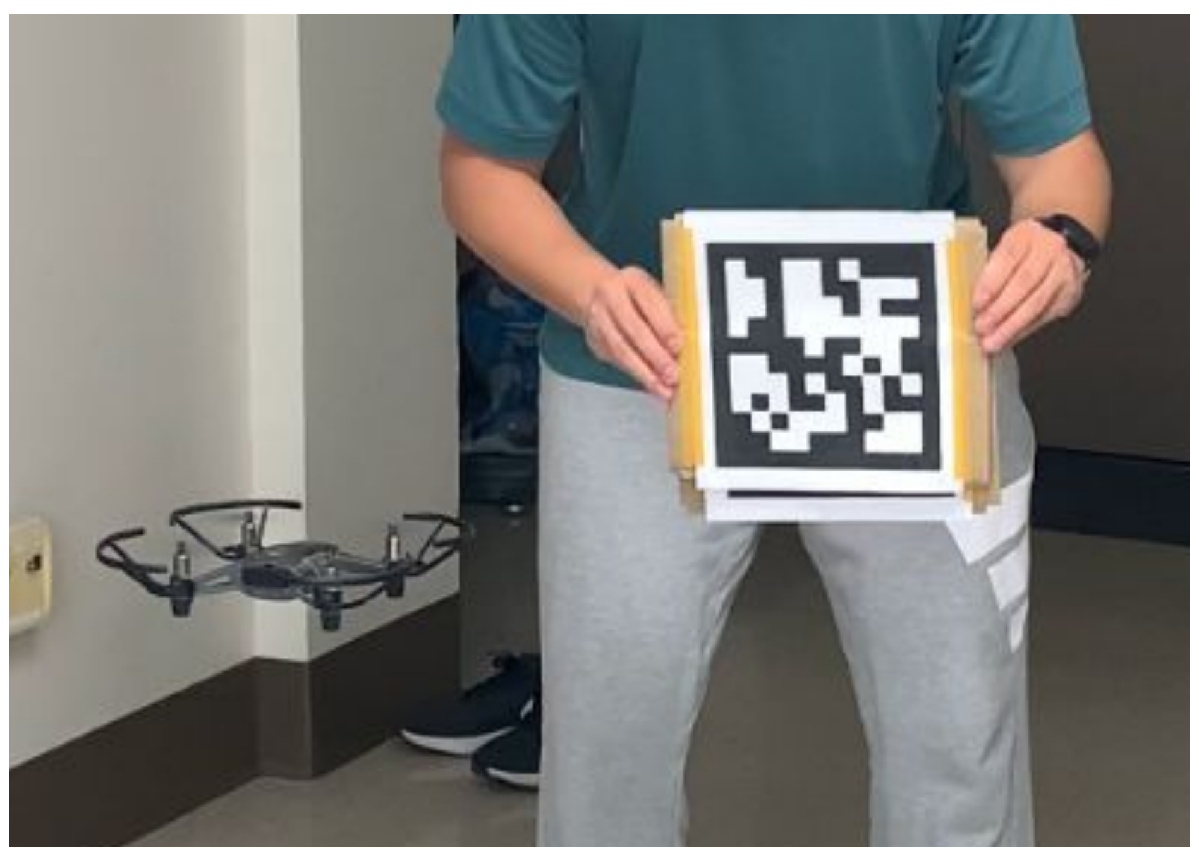


- HNN transforms the input pattern to a newly generated pattern.
- Compare generated pattern with saved patterns.
- If the generated pattern matches a saved pattern, send the associated commands to the drone.

Results

- 20 iterations with 0-30 flipped bits were tested for robustness.
- Recognized correct patterns 100% of the time with zero noise.
- Performs accurately up to 5 randomly flipped bits.





- Detects patterns from 8½ ft away.
- False detections are more likely the further the pattern.
- Works in varying lighting conditions.
- Recognizes up to 10 patterns reliably.

Conclusion

- HNN is a feasible method to implement a robust, CPU-based computer vision system for autonomous pattern-based drone flight.
- Using lightweight OpenCV filtering can achieve sufficient close range detection of patterns.

Future Work

- Expand the HNN memory capacity to increase the number of recognizable patterns.
- Improve the image processing to recognize multiple patterns at once and reuse the same pattern.
- Utilize evolutionary algorithms to optimize the number of neurons and patterns.

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