Learned Tactics for Asset Allocation
ICCRTS ‘13

Dr. David D’Ambrosio

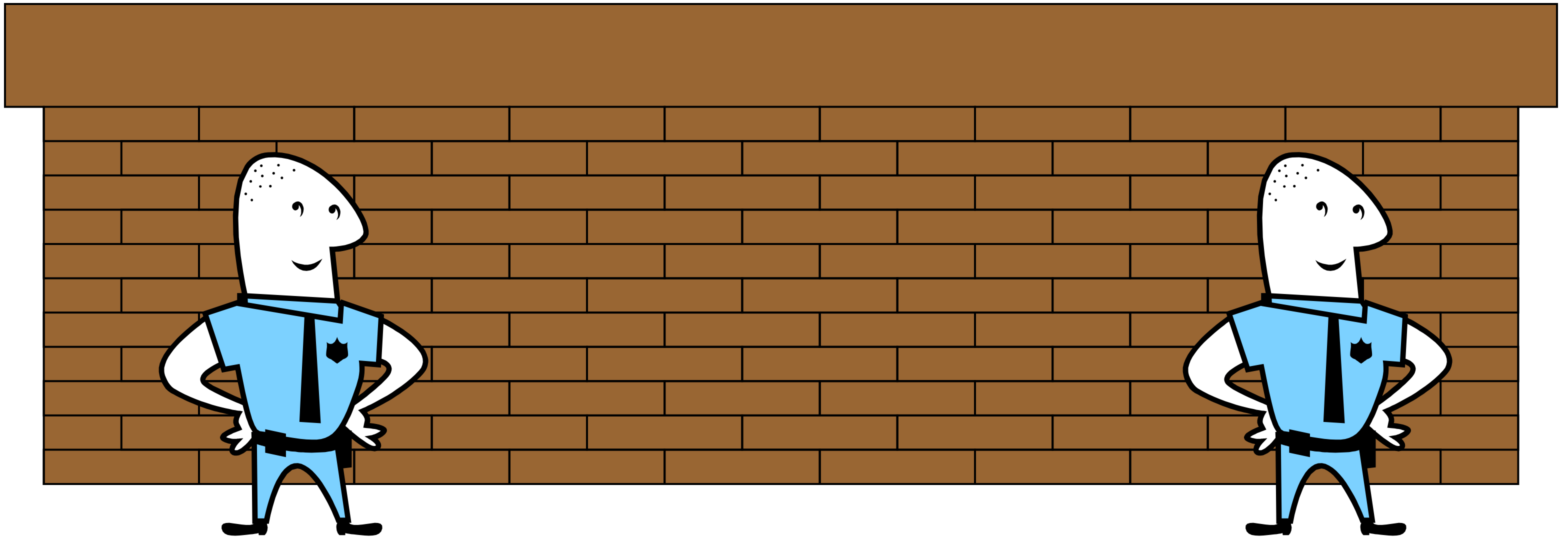
SPAWAR Systems Center Pacific

C2 Technology & Experimentation Division

June 2013

Asset Allocation Tactics

- Defining tactics for C2 is a complex task
- Increased available information makes it even harder
- A major problem is allocating assets for surveillance or defense



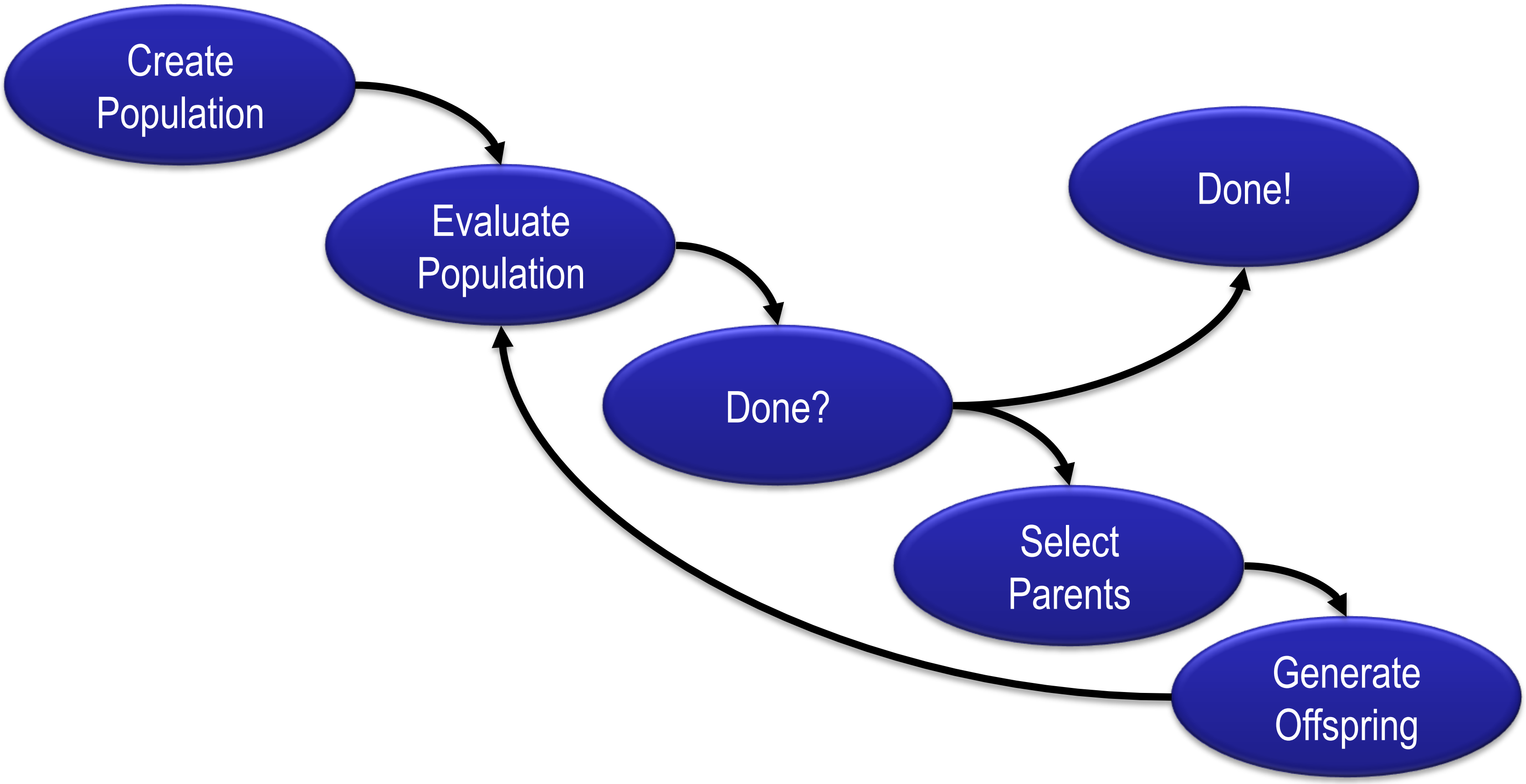
Applying Machine Learning

- Artificial intelligence (AI) and Machine Learning (ML) can mitigate this difficulty
- However, it can be difficult to assess their applicability and effectiveness
- This presentation demonstrates a ML technique for asset allocation and proposes a domain to evaluate such approaches

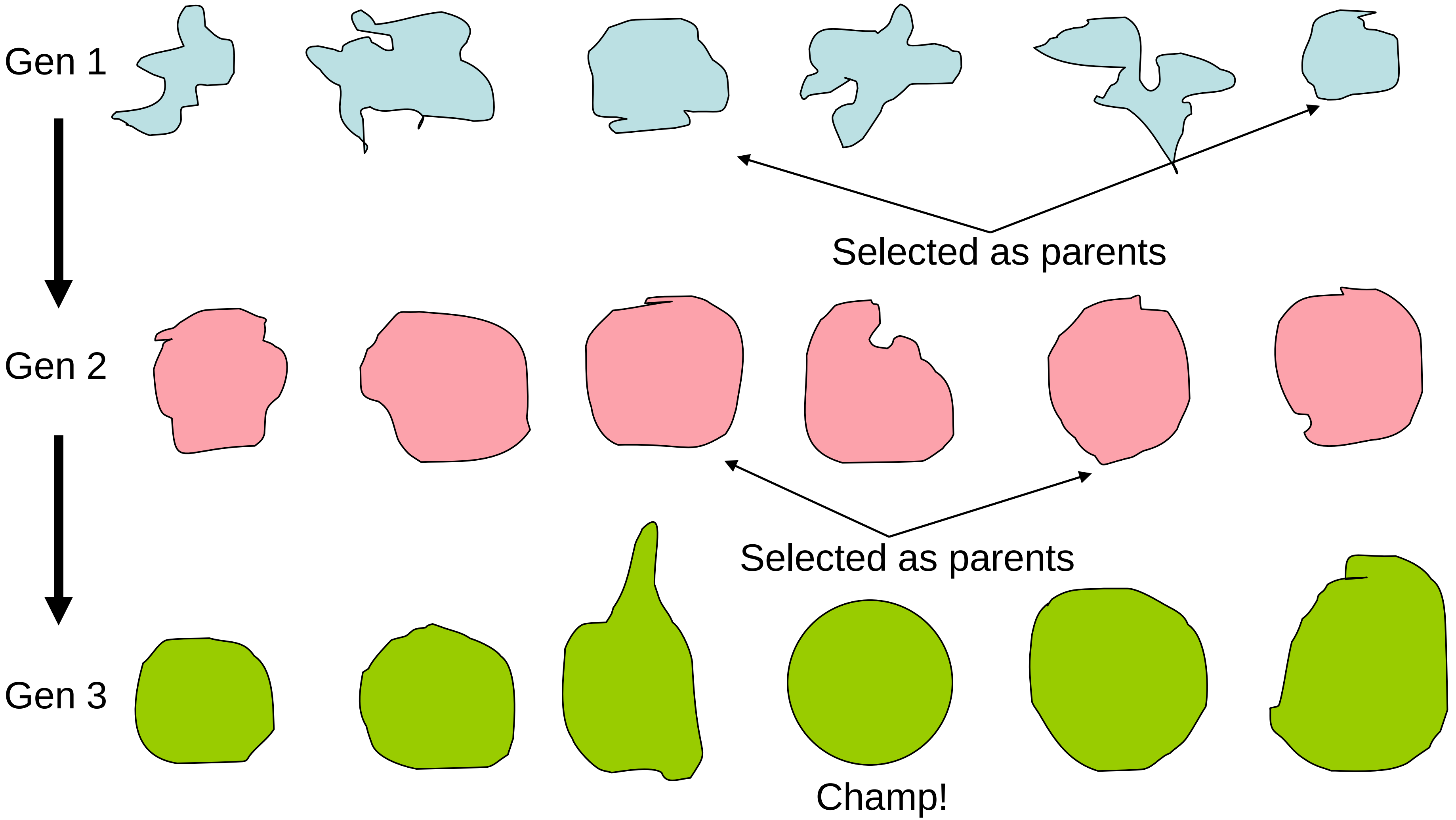
Outline

- Background: Evolutionary Computation
- Background: HyperNEAT
- Approach: Multiagent HyperNEAT
- Patrol Experiment
- Results
- Discussion and Conclusion

Evolutionary Algorithms

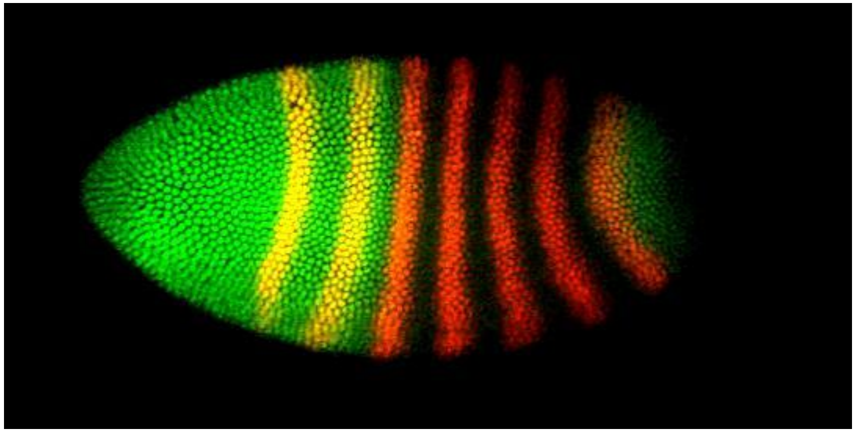


Example: Survival of the Roundest



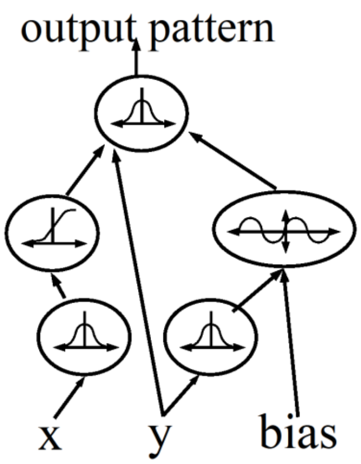
Generative and Developmental Systems (GDS)

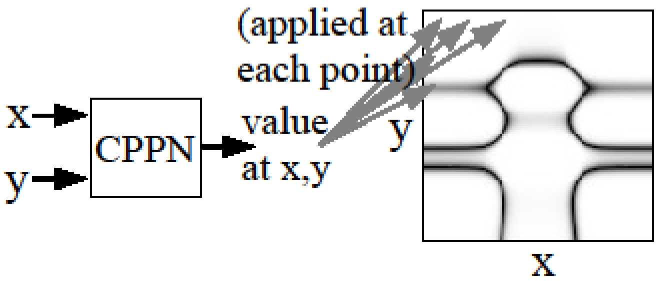
- Virtual DNA
- Motivated by biological development
- Exploit patterns and reuse information
- Describe a solution through a mapping



Gene Expression in a Fruit Fly Embryo
Meinhardt, 88

Compositional Pattern Producing Networks (CPPNs)





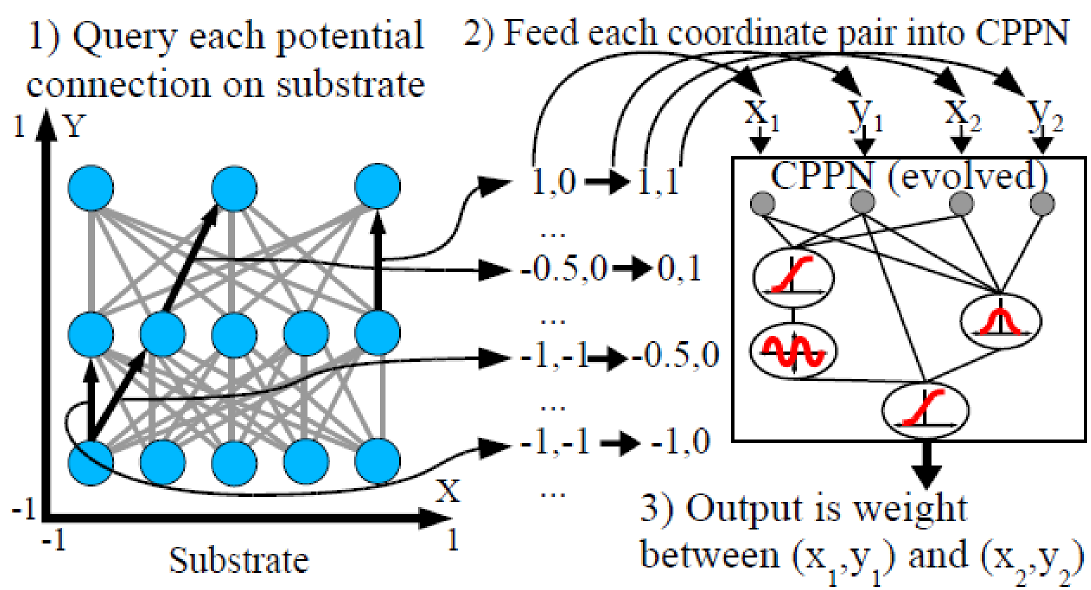
- Introduced by Stanley (2007)
- Composes functions that represent events in development
  - An abstraction of development
- CPPN takes a coordinate as input
- Outputs a weight for that coordinate
- Applying at all points creates a pattern in space
  - In this case a 2D image
- Sampling possible at any resolution or dimensionality

HyperNEAT

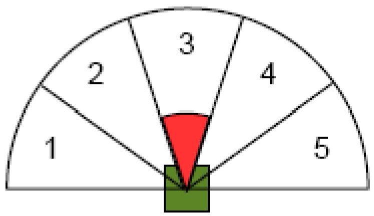
- Hypercube-based NeuroEvolution of Augmenting Topologies (Stanley, D'Ambrosio, and Gauci 2009)
  - Co-invented by myself, Gauci, and Stanley
- An abstraction of embryo development
- Combines Compositional Pattern Producing Networks (CPPNs) and NEAT (Neuroevolution of Augmenting Topologies)
- Uses geometric information to create a neural network

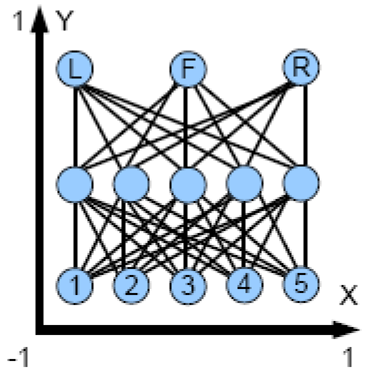
HyperNEAT

- ANNs are made up of weighted connections
- A connection can be defined by its end points
  - {x1, y1}, {x2, y2}
- A four-dimensional CPPN gives us:
  - CPPN(x1,y1,x2,y2) = 4D pattern or 2D connection pattern



Substrates

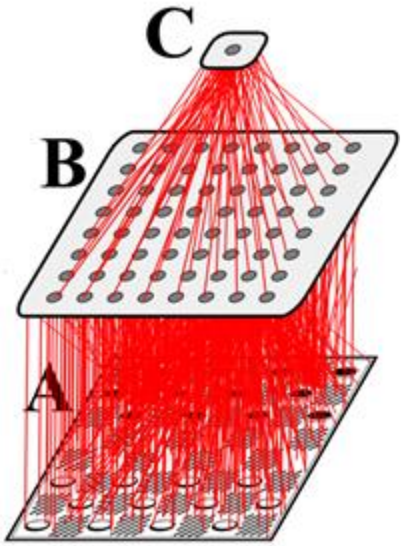




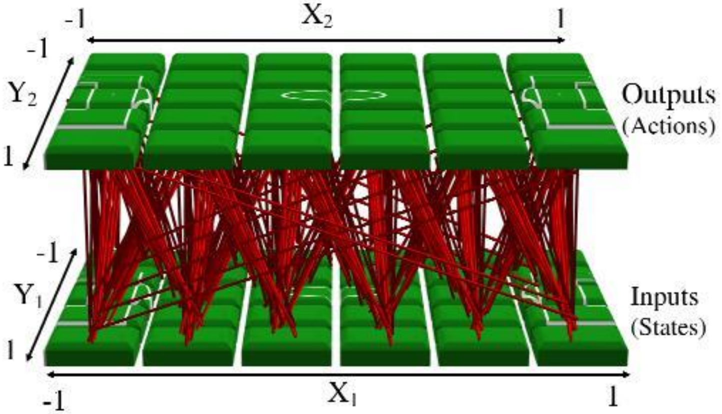
- Substrate is a geometric arrangement of neurons for an ANN
- The neurons are arranged to exploit the geometry of the problem
  - e.g. Left sensor related to left effector
- Can be any size, shape, or dimensionality

High-Level Substrates

Checkers by Gauci

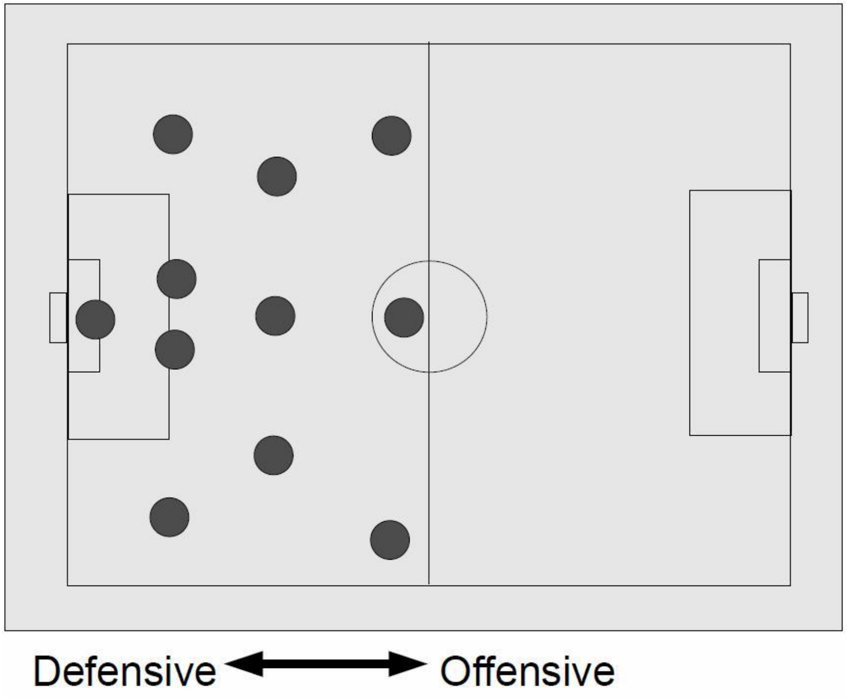


Robocup by Verbancsics

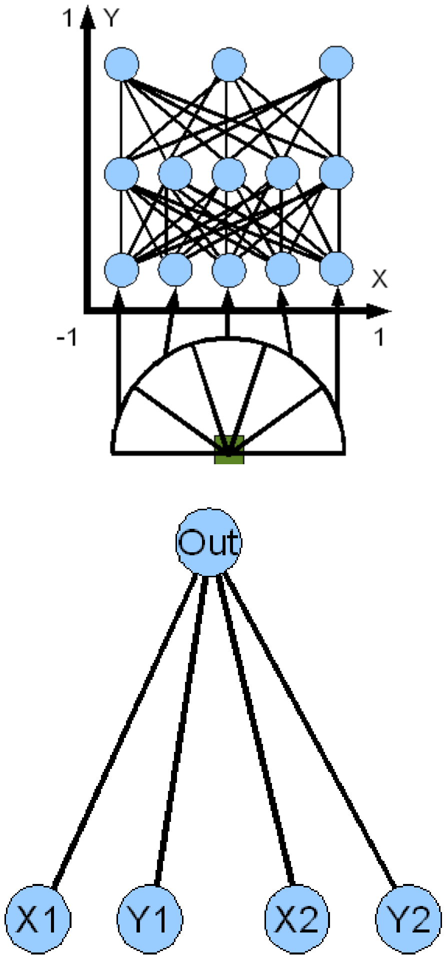


Teams and Policy Geometry

- Teams have a geometry
- Introduce the concept of *policy geometry*, that is, how policies are distributed among the team
- Teammates share a number of skills
- Goal: Generate policies as a function of geometry

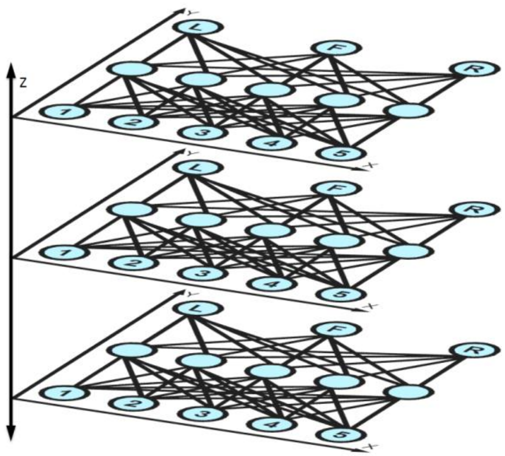


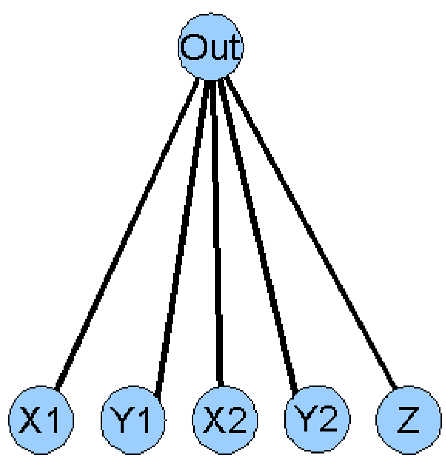
Multiagent HyperNEAT



- Extends HyperNEAT to elegantly encode multiple agents in a single genome
- Homogeneous team
  - A substrate representing a single agent is used
  - {x1,y1,x2,y2} input to CPPN generating connectivity pattern
  - The generated ANN is copied to all agents on the team
  - Performance on the task is tested

Heterogeneous Teams

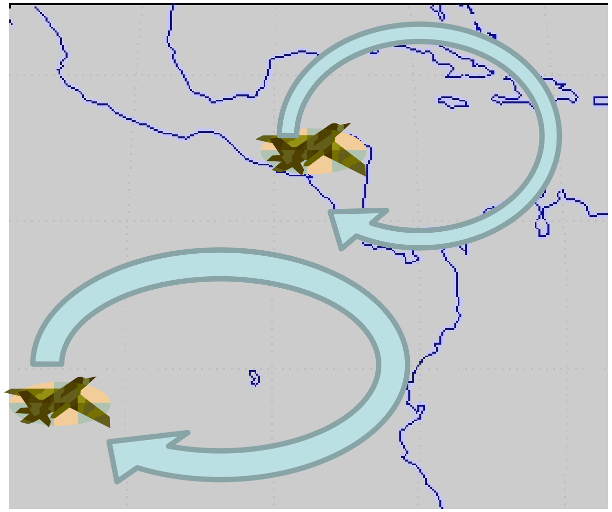




- Add new dimension ‘z’
- Creates a stack of networks
- Allows weights be computed as a result of location within an (x,y) agent and within the team (z)

Patrol Experiment

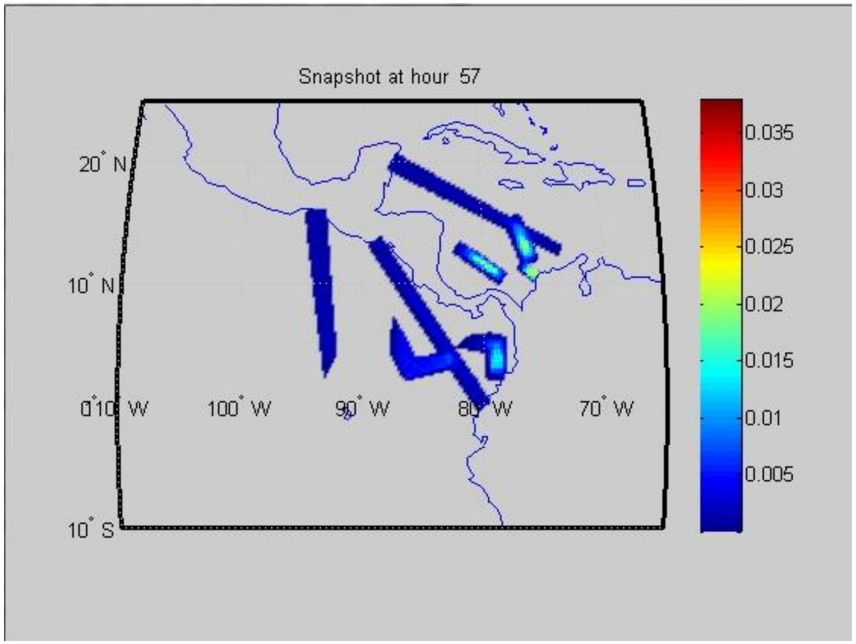
- Based on problem encountered by Joint Interagency Task Force South (JIATF-S)
- Contraband transported from South to Central America
- Need to detect and interdict vessels with contraband
- Act on intelligence
- Problem is difficult to solve, but easy to evaluate



Data Set

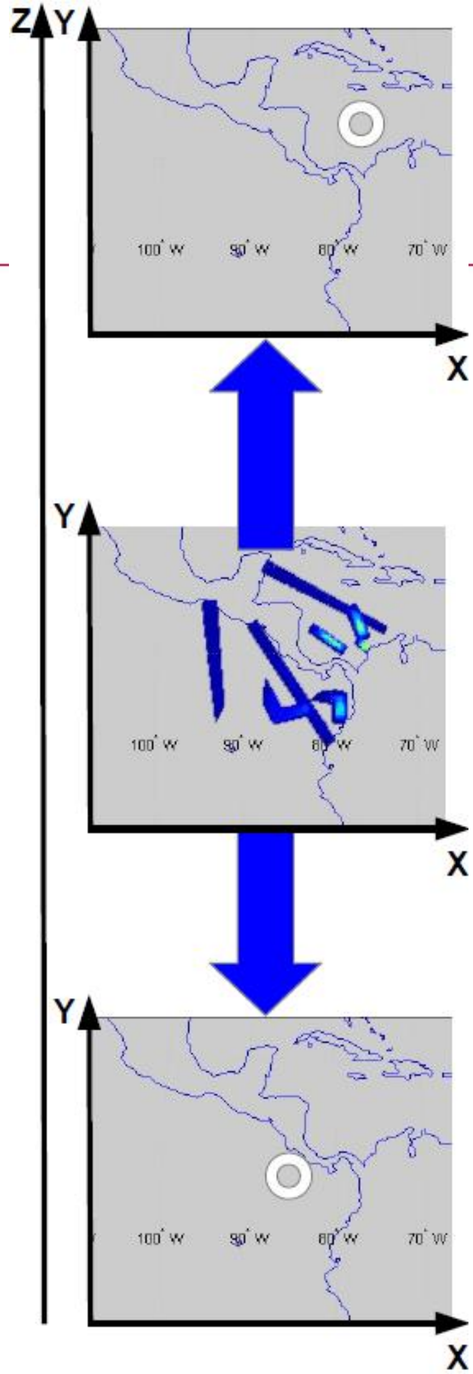
Patrol Experiment

- Goal: Successfully detect vessels with planes
  - 2 P-3 AIPs with visual range of 60nm
- Limited information on contraband carrying vessels
  - With uncertainty
- Patrol the area and detect as many boats as possible in 72 hour period
- Input: Probability of vessel being at location at a given time
- Output: Where each plane should go at current time

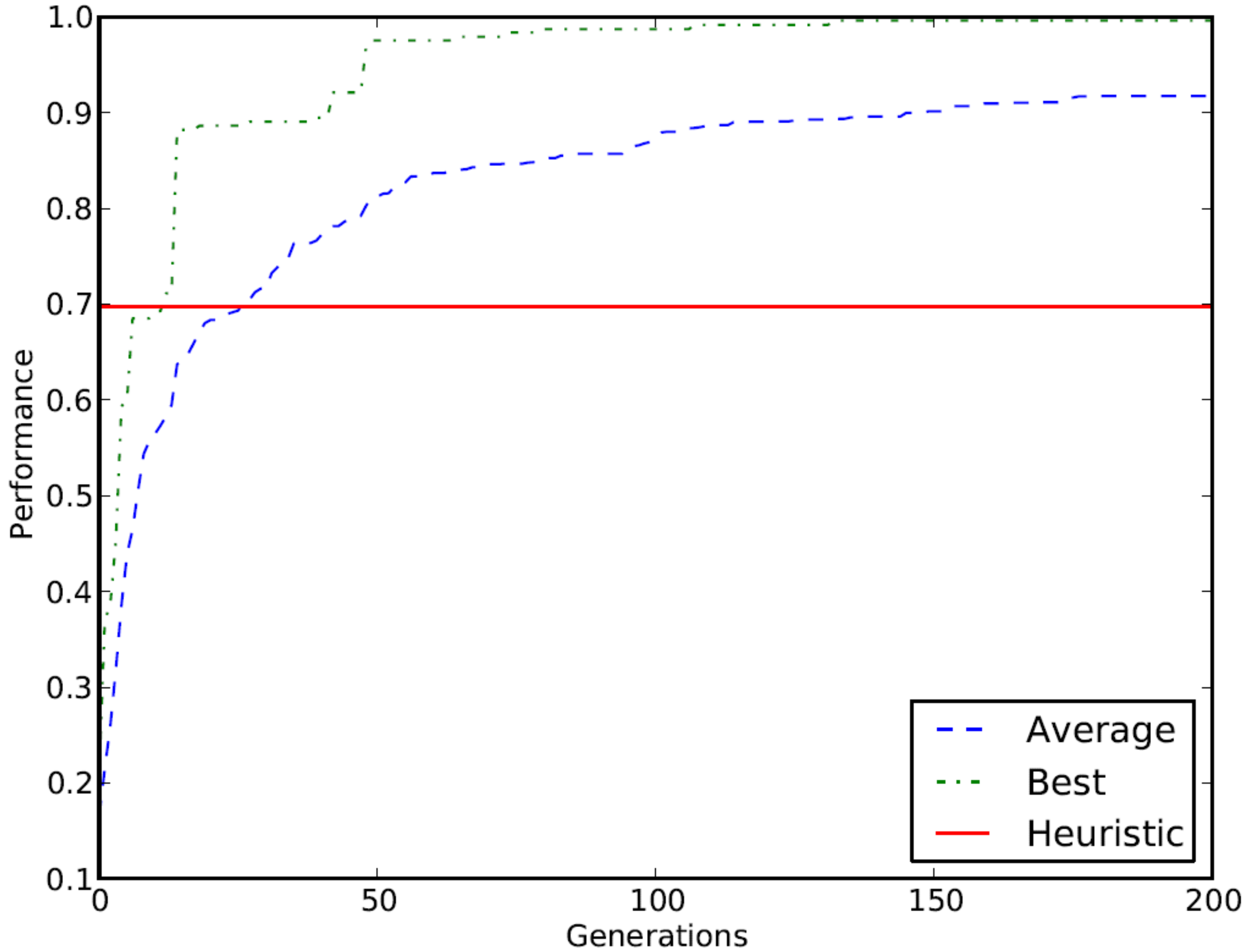


Substrate Design

- Heatmap probability acts as input
- Divided into 1x1 degree grid cells
- Input layers connect to two output layers
- The highest activation on each layer is where the plane will go next
- Compare to fixed policy of always moving towards highest probability



Results


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Performance
0
50
100
150
200
Generations
Average
Best
Heuristic

Discussion

- HyperNEAT quickly found effective patrol routes
- Found a variety of solutions:
  - Some found high traffic areas and stuck close
  - Some moved rapidly around the map
- May need to include additional costs (e.g. fuel)

Future work

- Include planning for interdiction (friendly ships)
- Substrate scaling for increased accuracy/faster training
- Comparison to other C2 approaches
  - e.g. human designed solutions

Systems Center PACIFIC

Conclusions

- Presented a relevant C2 domain
- Demonstrated a machine learning approach to solving the domain
- Opens the door for future comparison and additional benchmark tasks

Thank You

Questions?