An Agent-Based Predator-Prey Model with Reinforcement Learning

Rachel Fraczkowski, Megan Olsen
Department of Computer Science

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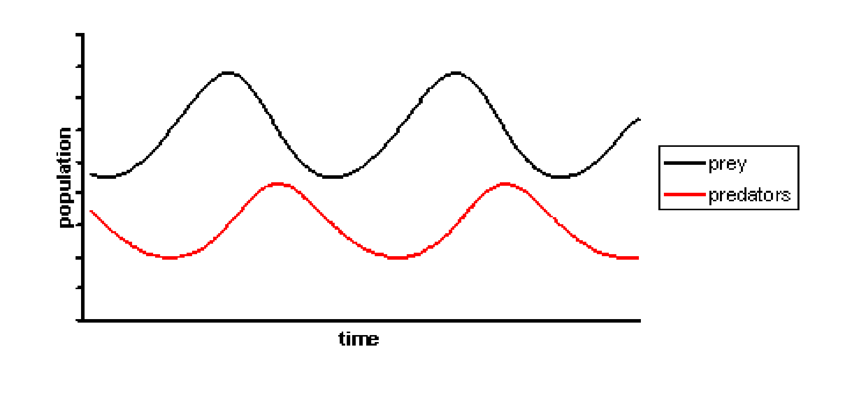
Studying Predator-Prey Systems

- Impact of Environmental Scenarios
  - Invasive Species
  - Human Impact Decisions
  - Extinction

- Simulation Observations
  - Emergent behavior without cost of actual observation
  - Population Dynamics
  - Chasing Patterns
  - Homeostasis or Balance

Previous Work



- Lotka Volterra (1925)
- Cellular Automata & Biological Modeling (Ermentrout, 1993)
- Cellular Automata with Emotions (Olsen, 2010)
- Netlogo Agent-Based Model (Wilensky, 1999)

- **Goal: Agents learn biased random movement using Reinforcement Learning**

Introduction

Reinforcement Learning

Model

Simulation

Results

Conclusions

Reinforcement Learning in Psychology

- Reinforcement Learning is a method of learning which uses rewards and punishments and scheduling in order to elicit a specific behavior or action.
- B. F. Skinner's Box (1938)
- Goal of RL: To increase or decrease the probability of action occurring in the future.

Four Types of Reinforcement

Positive Reinforcement : Positive stimuli given in order to increase behavior	**Negative Reinforcement:** Aversive stimuli added in order to increase behavior
Punishment: Aversive stimuli added to decrease behavior	**Extinction:** Behavior fades when it is no longer enforced

Reinforcement Learning in Computer Science

- Reinforcement learning is an area of machine learning
- Software agents take actions in environment
- Maximize notion of cumulative reward
- Examples
  - Game theory
  - Simulation-based optimization
  - Control theory
  - Operations research
  - Information theory
  - Statistics
  - Genetic algorithms

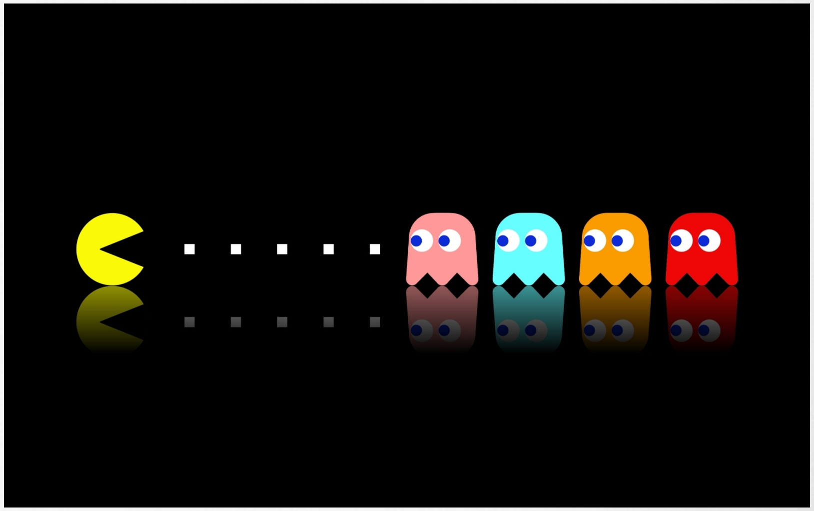


Image from technetcrew.com

Reinforcement Learning in Our Model

- Predator learns to chase prey
  - Reward movement towards prey
  - Punish movement away from prey
- Prey learns to escape predator
  - Reward movement away from predator
  - Punish movement towards predator

Image from stephsnature.com

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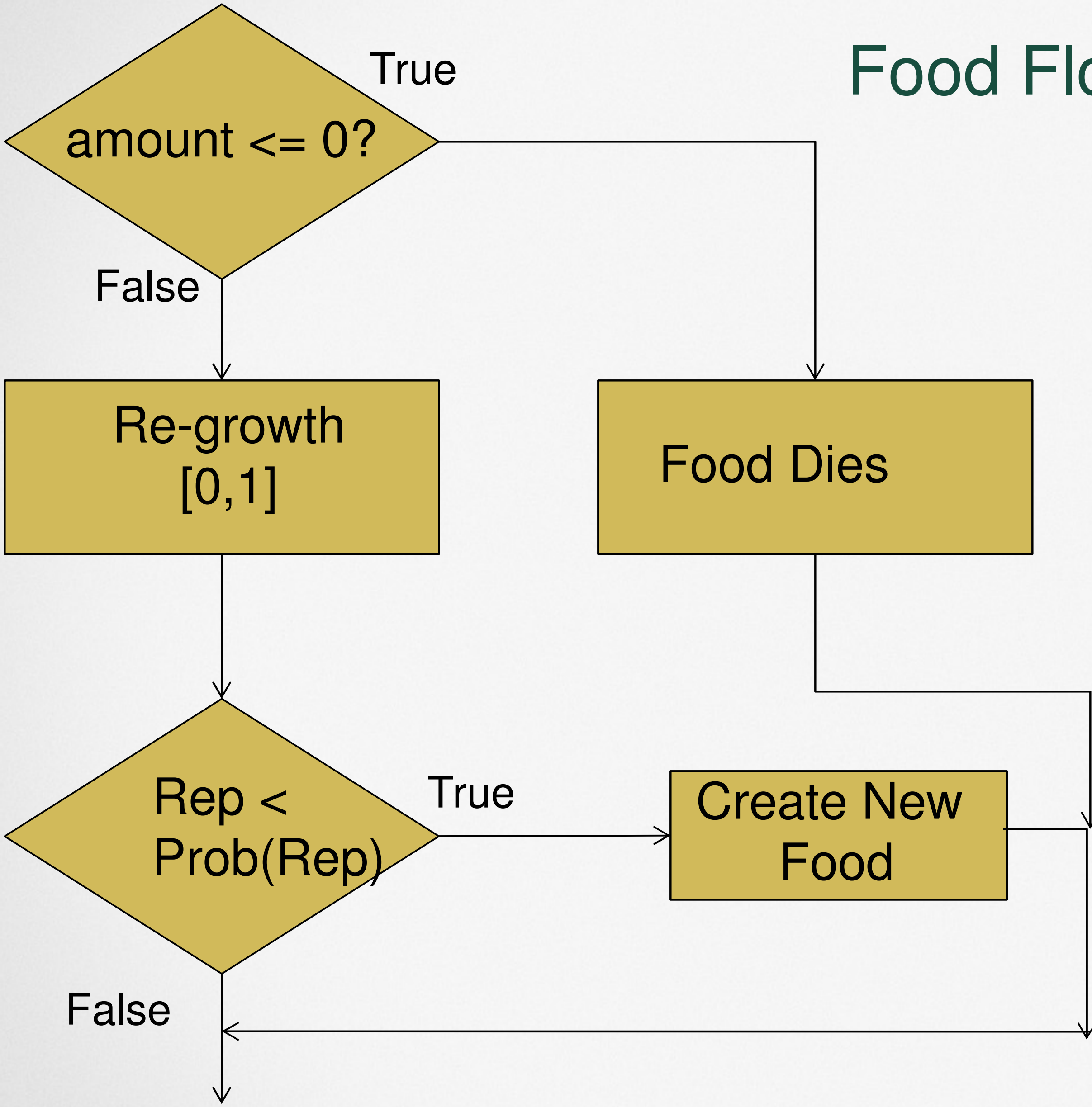
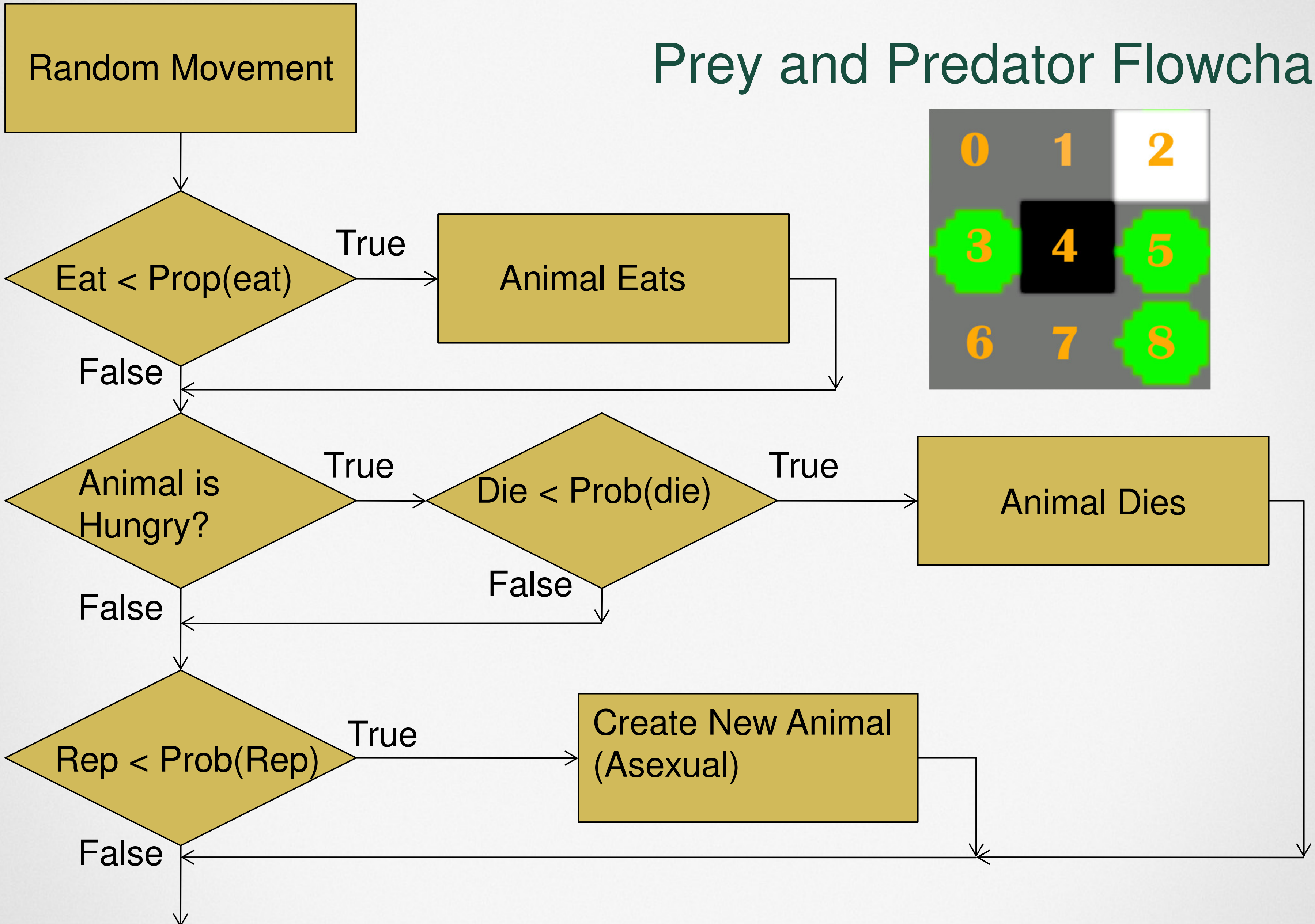
Our Model

- MASON Framework
- 2D Grid
  - Torus
- Agents
  - Food
  - Predator
  - Prey

Food Flowchart - Timestep



Prey and Predator Flowchart




Predator

Agents Learn Movement Probabilities

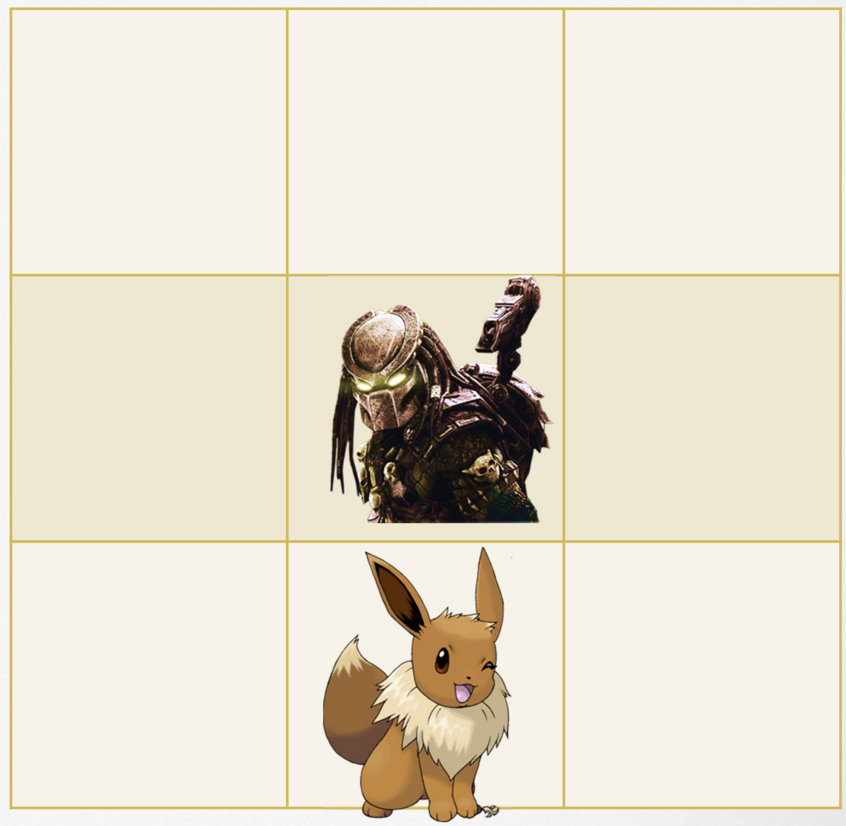

Prey

Movement Array

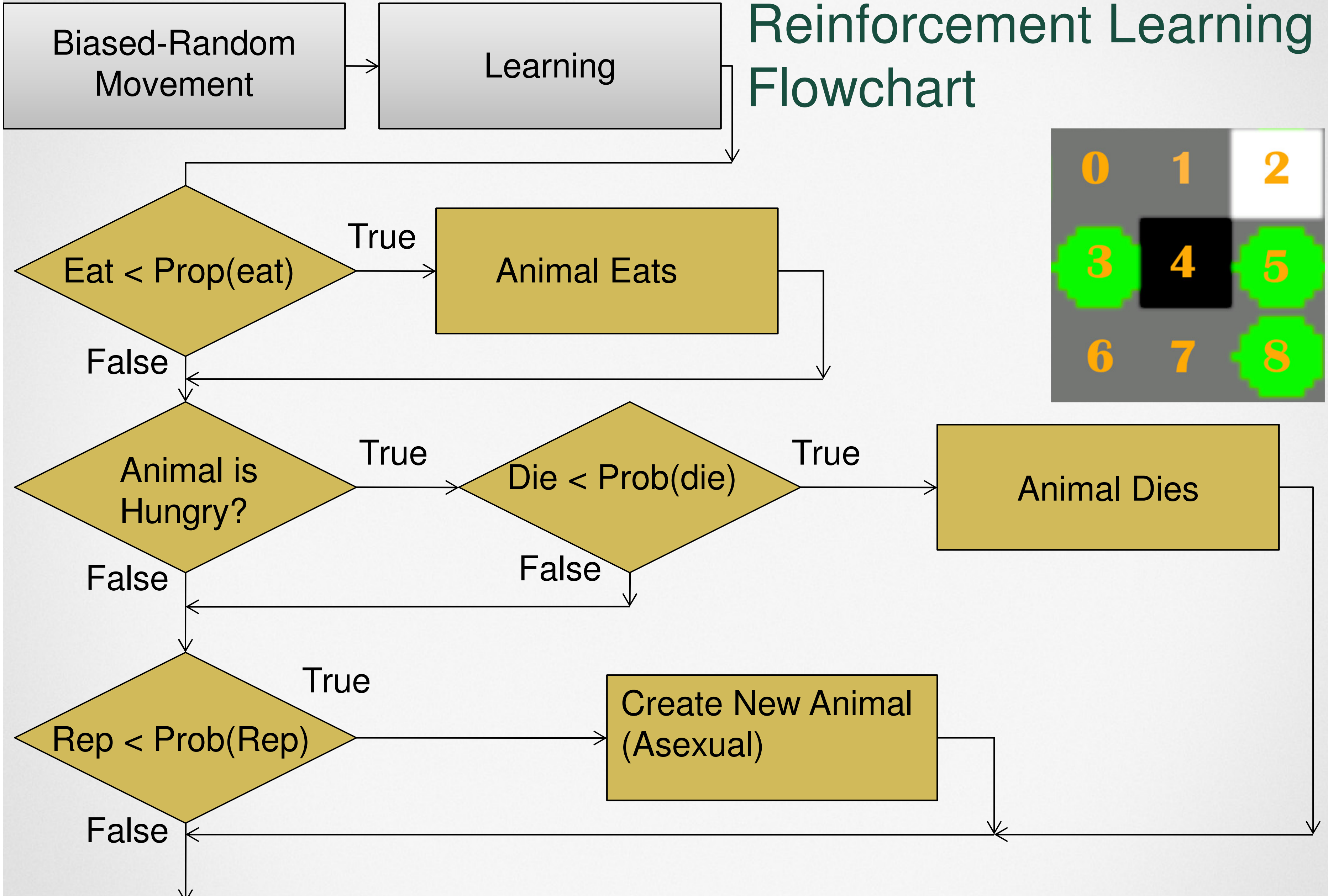
{ 11.11, 11.11, 11.11,
11.11, 11.11, 11.11,
11.11, **11.11**, 11.11 }

Learned Array

{ 6.235, *1.235*, .235,
6.235, 6.235, .235,
6.235, *67.11*, 6.235}



Reinforcement Learning Flowchart



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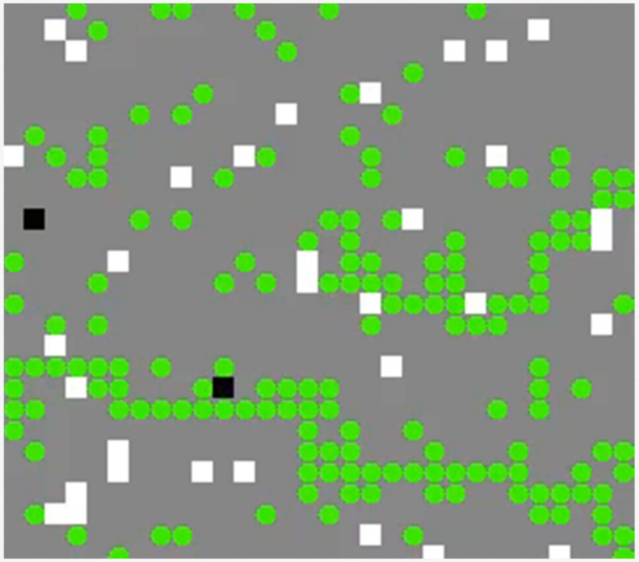
Simulation Sample

World

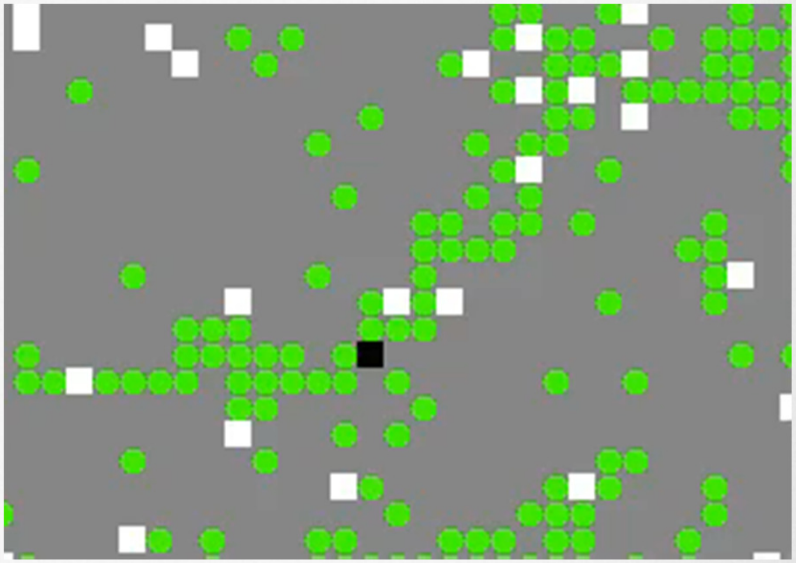
Predator

Prey

Food



No Learning



Learning (Prey)

Analyzing the System

- Goal: Have agents learn to move in biased manner from their environment and experience
- Hypotheses:
  - The species learning will have an advantage in the system
  - With co-learning, agents will learn from one another
- Phases:
  - No Learning
  - Predator Learning Only
  - Prey Learning Only
  - Predator and Prey Learning

Simulation

15 replications for each set of parameters

Prey > Predator (population and reproduction)

Reproduction rate > death rate

Parameters	Predator	Prey
Population	25-100	200-800
Reproduction Rate	5%-20%	10%-20%
Initial Death Rate	.1%-10%	.1%-1%
Hunger Minimum / Reproduction Age	15 timesteps	12 timesteps
Hunger Death Mod	1x-1.5x	1x-1.5x

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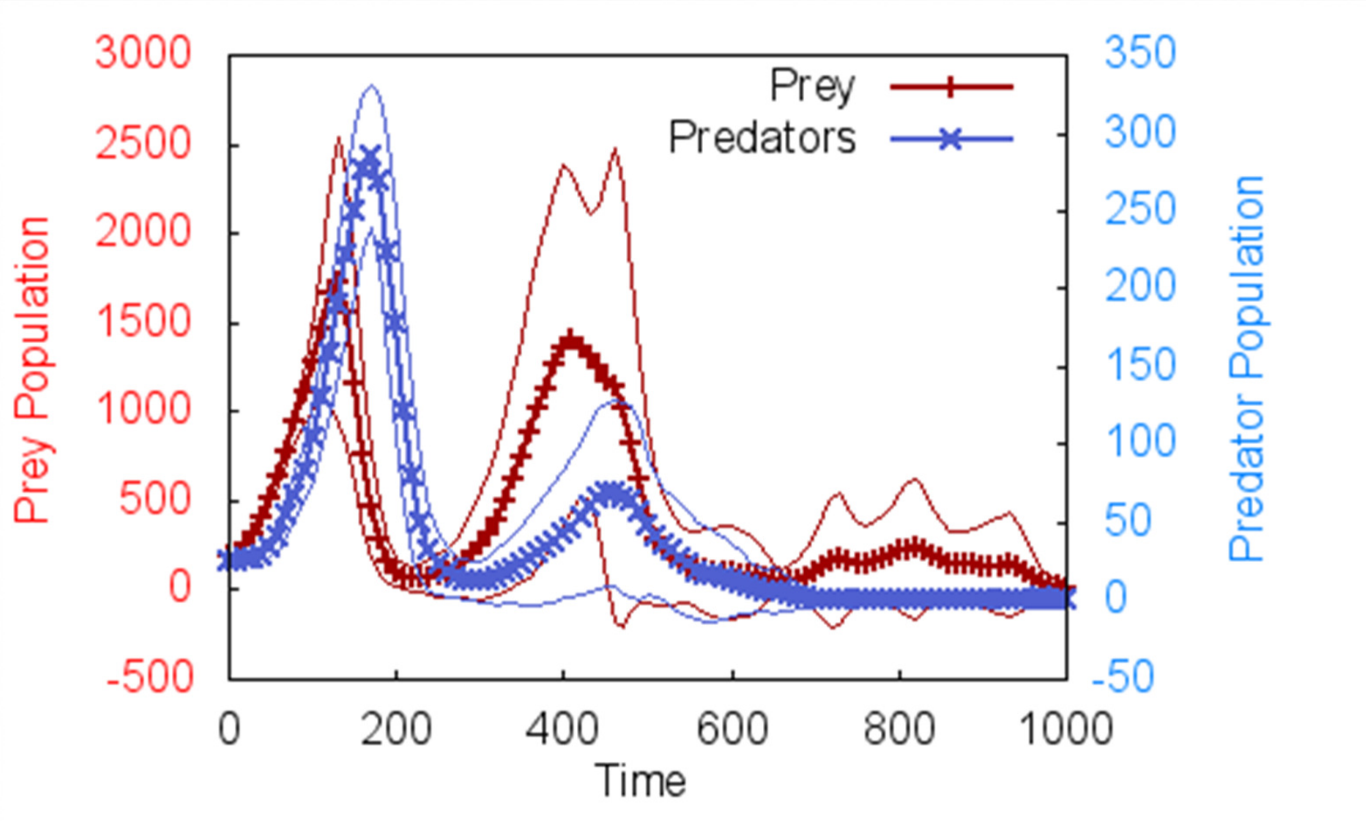
Preliminary Results



Preliminary Results

- Prey learning shows improvement
- Predator and Prey Learning to stay more often
- Both Learning shows improvement from Predator learning

	outran	**caught**	**prey Stay**	**pred Stay**	**ending**	**prey Count**	**pred Count**	**prey Eat**	**prey Hunger**	**pred Hunger**
prey learn	**76%**	**60%**	**80%**	**60%**	**60%**	**72%**	**56%**	**56%**	**68%**	**64%**
pred learn	20%	24%	20%	**72%**	4%	12%	12%	20%	12%	4%
both learn	28%	32%	**52%**	**72%**	4%	16%	20%	32%	12%	0%

Learning Has an Impact

- Predator and Prey experience improved behavior (eating)
- Prey system has expected outcomes
- Predator system has unexpected outcomes
- Both learning shows an average of other two systems

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Conclusions

- Agent-Based Model with reinforcement learning agents
- Observed expected population fluctuations
- Prey learning and Both learning show improvements to system
- Predator & prey learning to stay

Future Work

- More parameter testing and results
- Changes in learning algorithm
- Agents could learn more complex cognitive functions
  - Memory
  - Emotional Experience