EVOLUTIONARY DESIGN OF PARTICLE SWARMS

Science with Python, Celery, and PyGame

by Benjamin Bengfort

DistrictDataLabs

Craig Reynolds was originally inspired to design simulated flocks by sitting on a bench watching the behavior of birds flying together. He designed **BOIDS** (http://www.red3d.com/cwr/boids/) as simple agents whose actions in concert led to globally emergent behavior. In both algorithms and nature, large flocks can move together in complex formations and patterns with only a few simple local rules.

THE STORY OF HOW WE USED PYTHON TO DO SCIENTIFIC EXPERIMENTS

THE EXPERIMENT:

CAN WE USE EVOLUTIONARY ALGORITHMS TO DESIGN A PARTICLE SWARM SYSTEM THAT CAN OUTPERFORM A HUMAN DESIGN?

NumPy

pygame

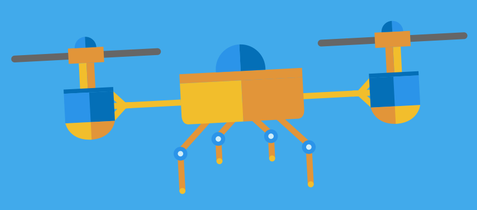
UNIVERSITY OF MARYLAND 18 56

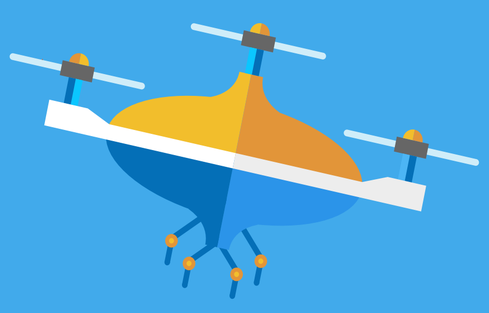
PARTICLE SWARMS

PROBLEMS IN THE PHYSICAL WORLD CAN BE EFFICIENTLY SOLVED USING SIMPLE AGENTS THAT ACT IN CONCERT TO DEMONSTRATE GLOBALLY EMERGENT INTELLIGENCE

COMPLEX NAVIGATION
SENSOR DEPLOYMENT
FIRE FIGHTING
CONSTRUCTION

MANY ROBOTIC IMPLEMENTATIONS ARE NOW BECOMING CHEAP ENOUGH TO WARRANT THE USE OF ROBOTIC FLOCKS.





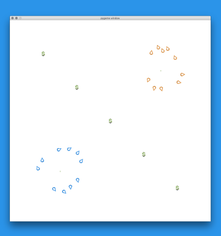
OUR EXPERIMENT: SEARCH AND RESCUE

CHARACTERISTICS:

- Two teams and bases
- Resources depots
- Find, collect, and return
- Large world
- Periodic boundaries

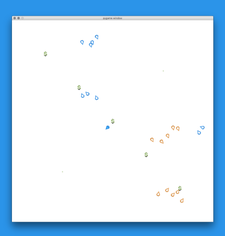
CONSIDERATIONS:

- Exploit vs. Explore?
- Competitive - limited resources
- Theft and collisions
- Economy of design
- Adapt to environment

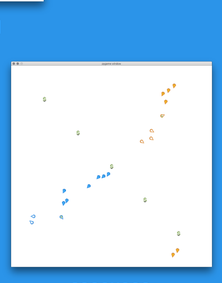


INITIAL SPREAD

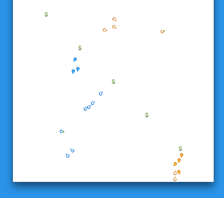
HUMAN DESIGN: MOVEMENT BEHAVIORS



EXPLORING FLOCKS



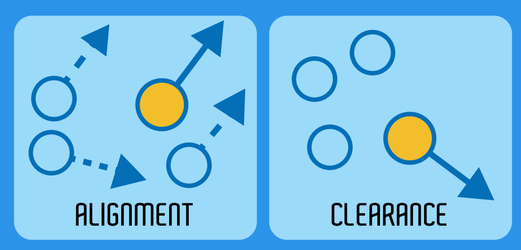
CARAVANS

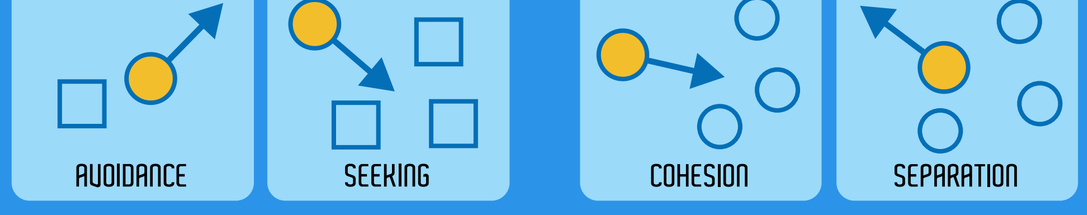


COLLECT & GUARD

GATHERING & EXPLORING

BEHAVIOR EMERGES FROM LOCAL RULES





EVOLUTION

MODIFY BEHAVIORS OF A SWARM TO FIT A SPECIFIC DOMAIN TASK BY EVOLVING THE UNDERLYING COMPONENTS

- The dynamics parameters of velocity components
- The structure of the finite state machine

EVOLUTIONARY STRATEGIES (ES)
optimization of a genotype of real valued numbers.

EVOLUTIONARY PROGRAMMING (EP)
the evolution of the structure of Finite State Machines (an older definition of evolutionary programming) by modifying transitions and states.

(50/2) + 1 ELITE PARENT

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GENOTYPE
Component array and transitions for an individual particle

FITNESS
The number of resources collected against human design

PHENOTYPE
Behavior of the entire swarm in the simulation of the task

THE HUMAN TEAM: RODRÍGUEZ, A., & REGGIA, J. A. (2004). EXTENDING SELF-ORGANIZING PARTICLE SYSTEMS TO PROBLEM SOLVING. ARTIFICIAL LIFE, 10(4), 379-395.
THE EVOLVED TEAM: BENGFORT, B., KIM, P. Y., HARRISON, K., & REGGIA, J. A. (2014, DECEMBER). EVOLUTIONARY DESIGN OF SELF-ORGANIZING PARTICLE SYSTEMS FOR COLLECTIVE PROBLEM SOLVING. IN SWARM INTELLIGENCE (SIS), 2014 IEEE SYMPOSIUM ON (PP. 1-8). IEEE.