Bio-inspired Active Vision

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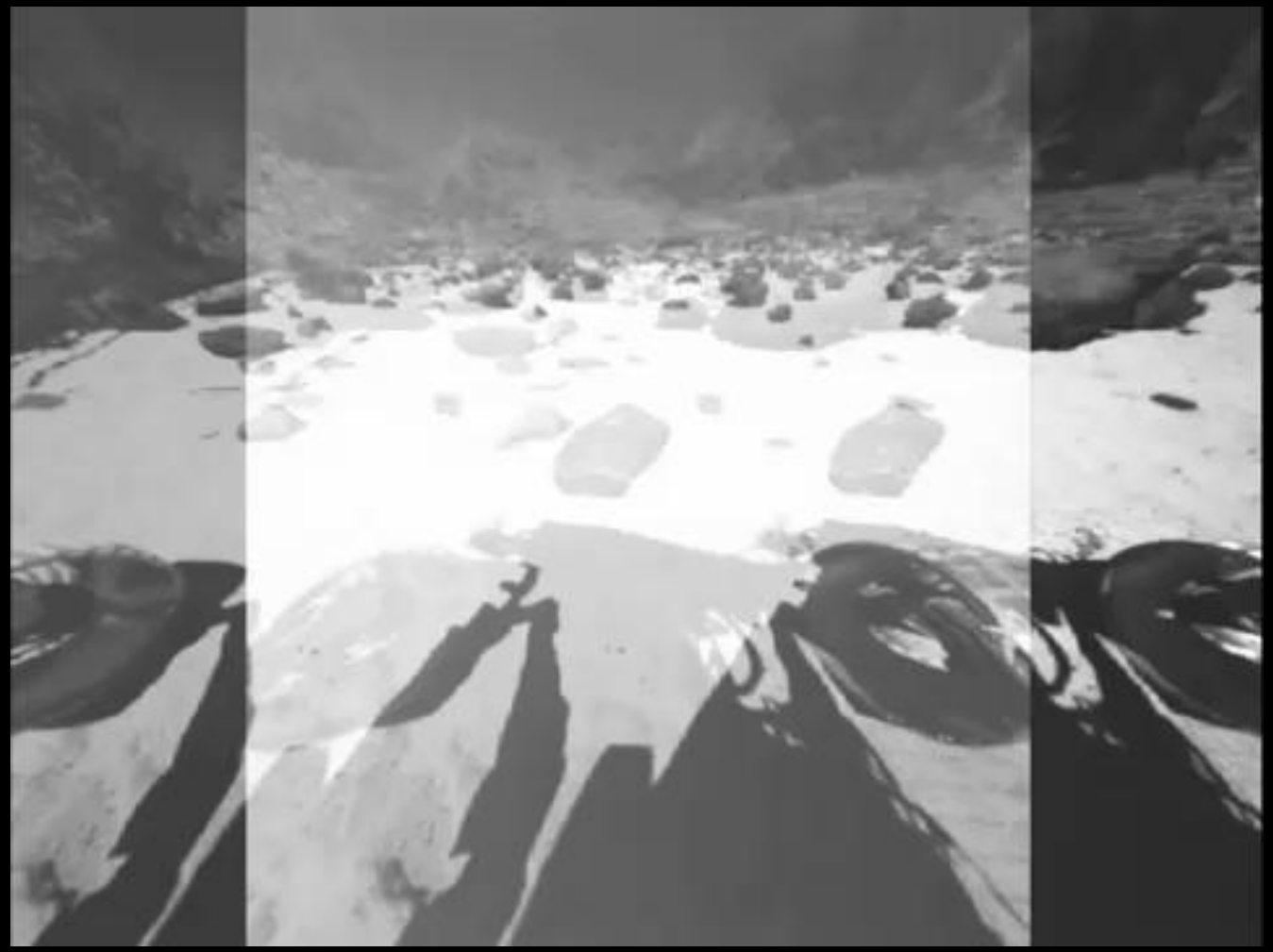
Traditional Computer Vision



Traditional Computer Vision

“Teaching a computer to classify objects has proved much harder than was originally anticipated”
Thomas Serre - Center for Biological and Computational Learning at MIT

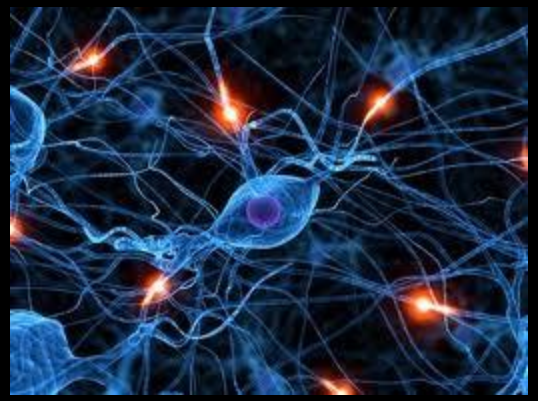
- **Specific template or computational representation is required to allow object recognition**

- **Must be flexible enough to account with all kinds of variations**

Biological Vision

"Researchers have been interested for years in trying to copy biological vision systems, simply because they are so good" ~ David Hogg - computer vision expert at Leeds University, UK

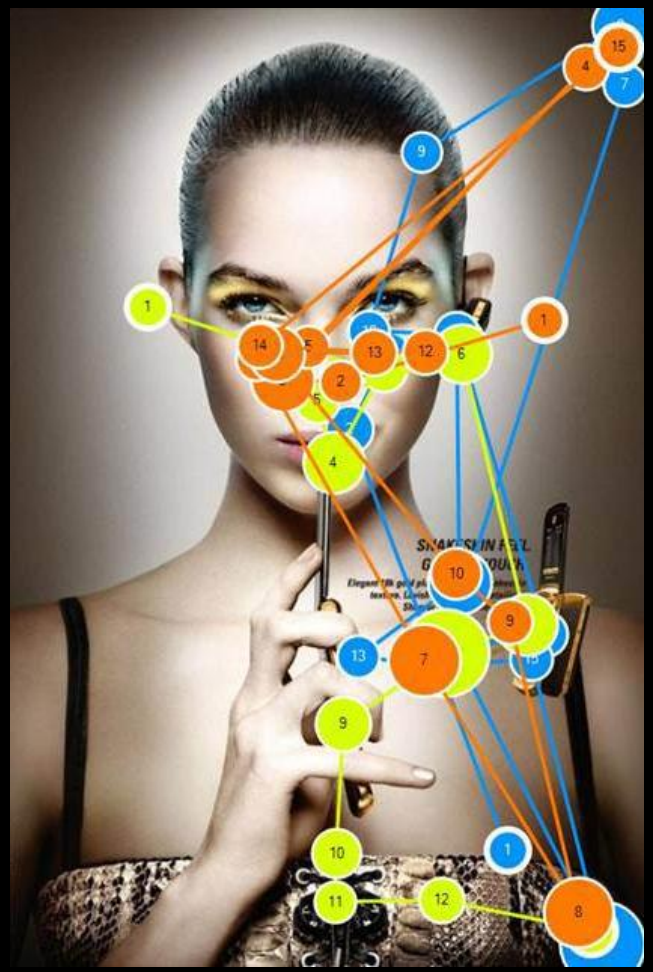
- **Highly optimized over millions of years of evolution, developing complex neural structures to represent and process stimuli**

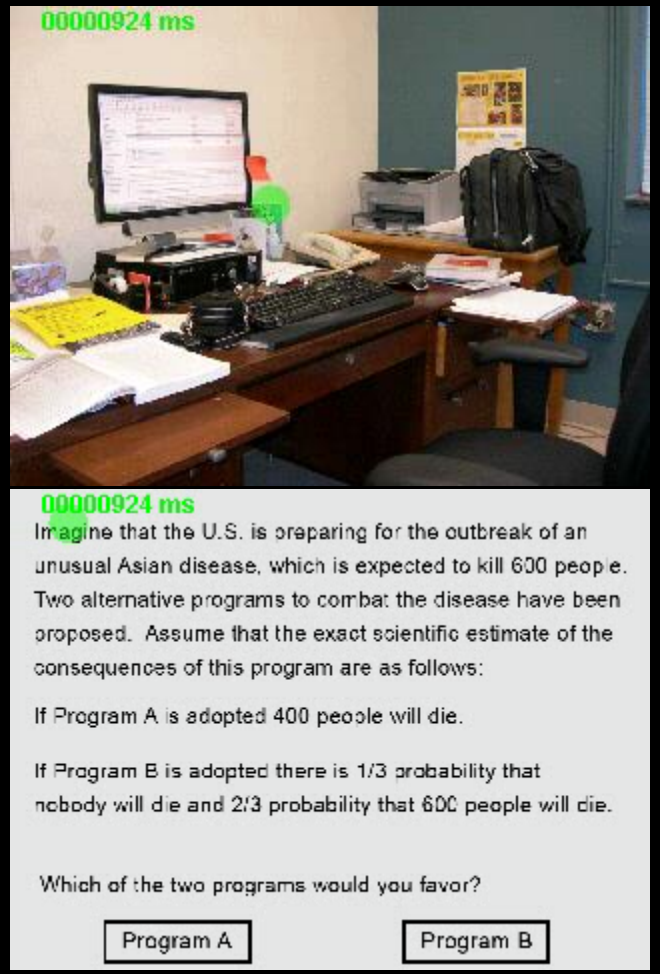


- **Superiority of biological vision systems is only partially understood**

- **Hardware architecture and the style of computation in nervous systems are fundamentally different**

Biological Vision





Seeing is a way of acting

Active Vision

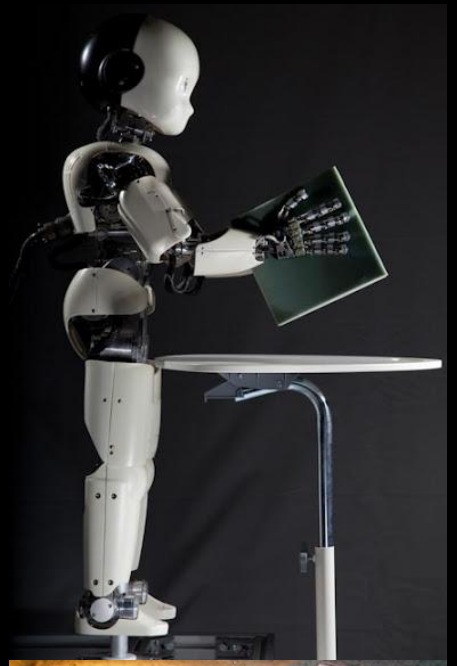
- Inspired by the vision systems of natural organisms that have been evolving for millions of years
- In contrast to standard computer vision systems, biological organisms actively interact with the world in order to make sense of it
- Humans and also other animals do not look at a scene in fixed steadiness. Instead, they actively explore interesting parts of the scene by rapid saccadic movements

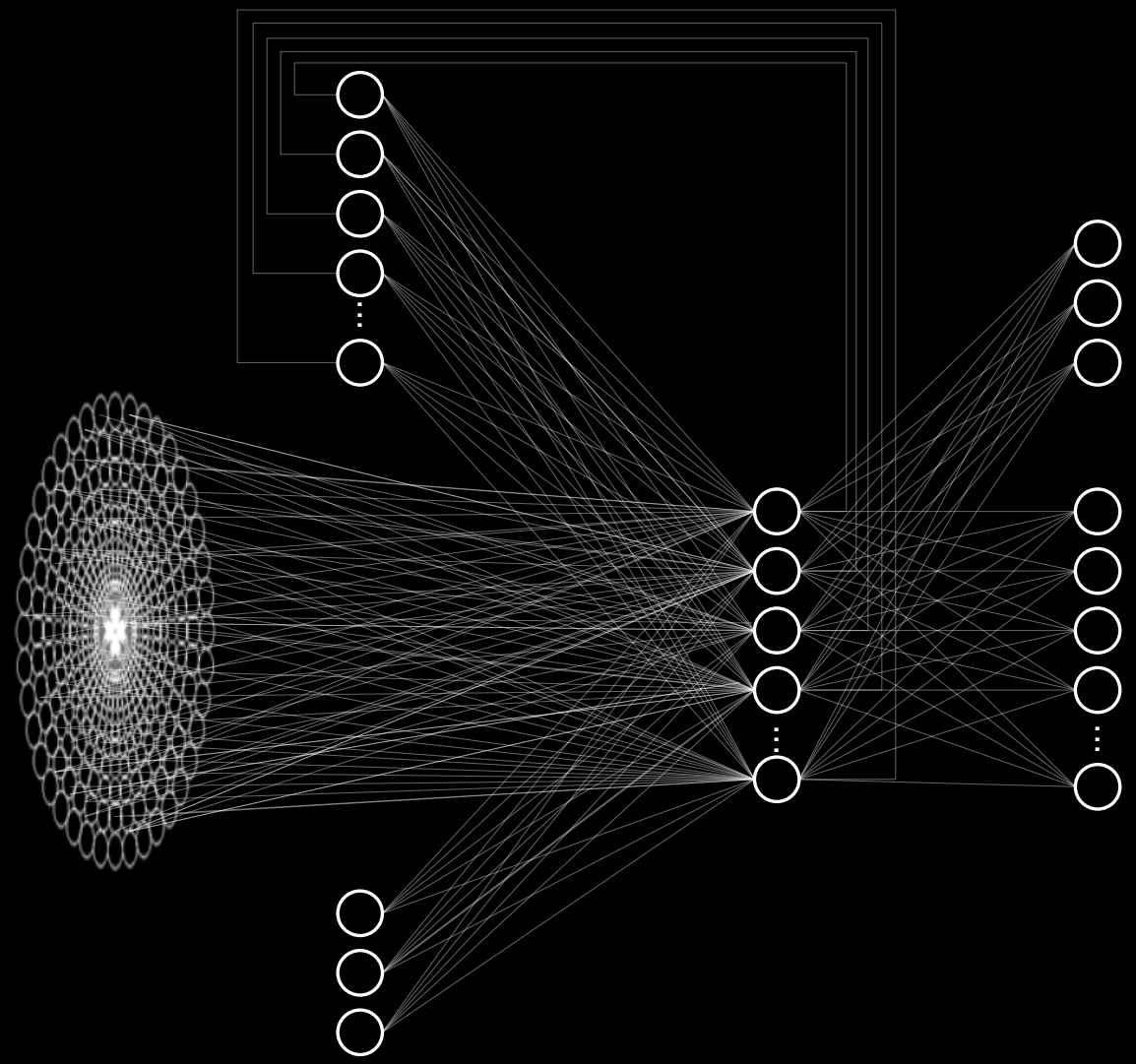
Creating Active Vision Systems

Evolutionary Robotics Approach

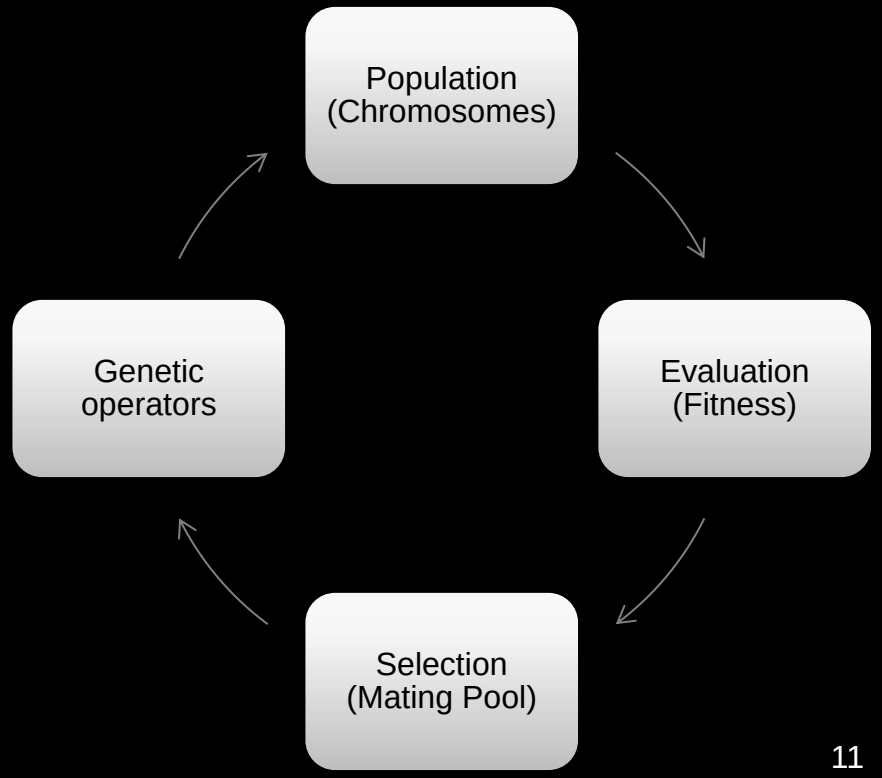
Evolutionary Robotics

- New technique for the automatic creation of autonomous robots
- Inspired by the Darwinian principle of selective reproduction of the fittest
- Views robots as autonomous artificial organisms that develop their own skills in close interaction with the environment and without human intervention
- Drawing heavily on biology and ethology, it uses the tools of neural networks, genetic algorithms, dynamic systems, and biomorphic engineering





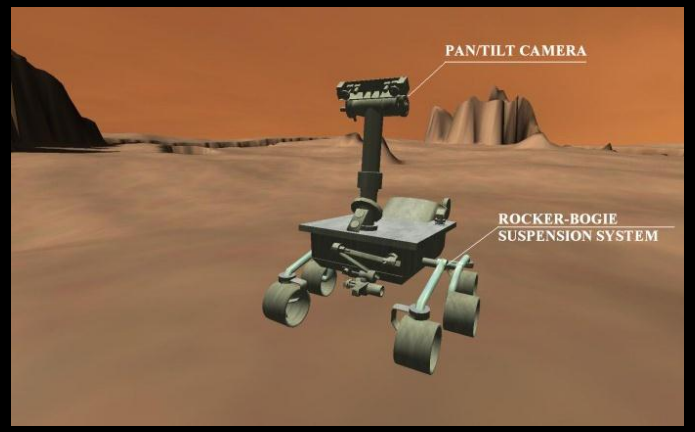
Genetic Algorithms (GAs) are adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic. The basic concept of GAs is designed to simulate processes in natural system necessary for evolution.

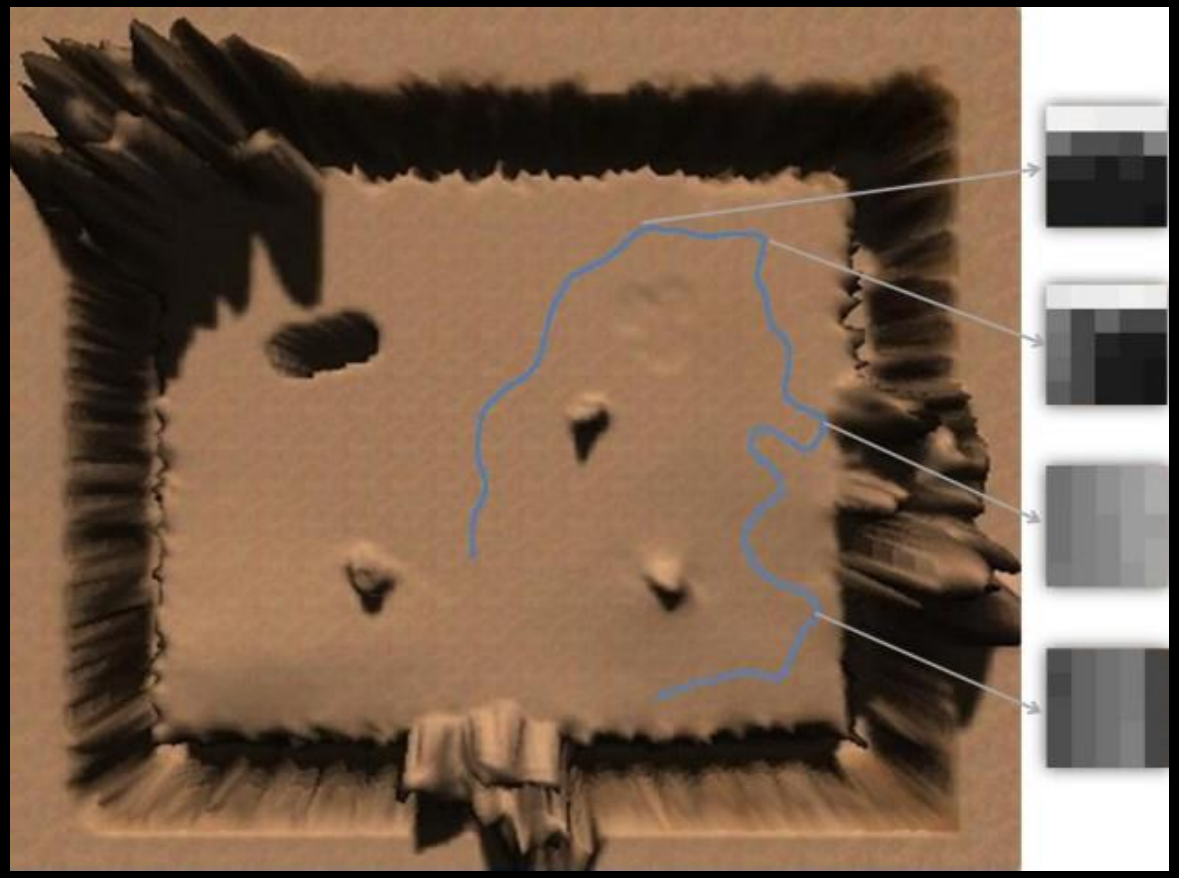


Artificial neural networks (ANNs) are very powerful brain-inspired computational models, which have been used in many different areas such as engineering, medicine, finance, and many others.

Related Research

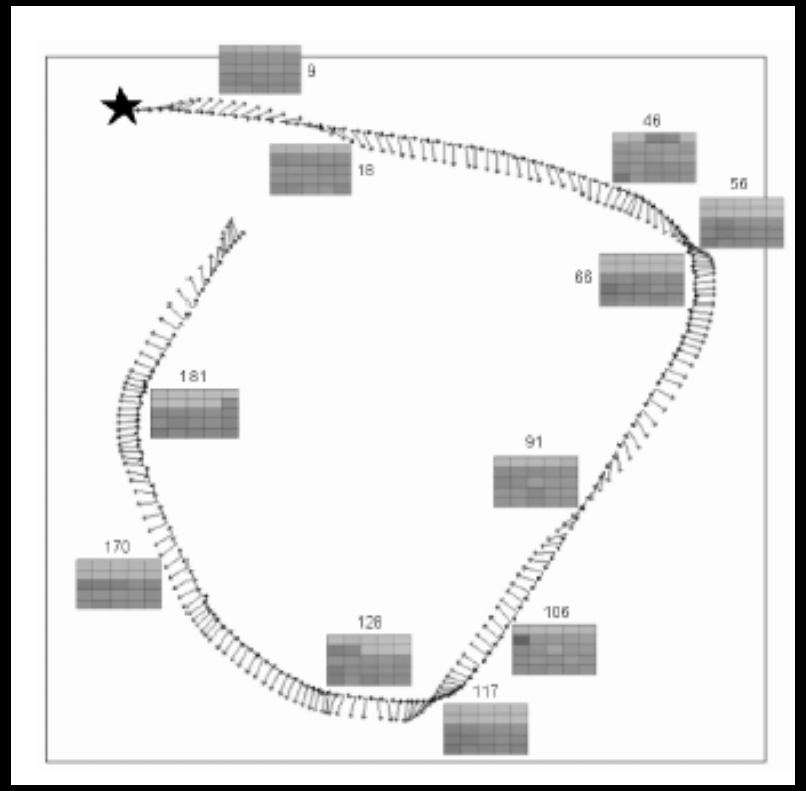
Mars Rover obstacle avoidance (Peniak et al.)





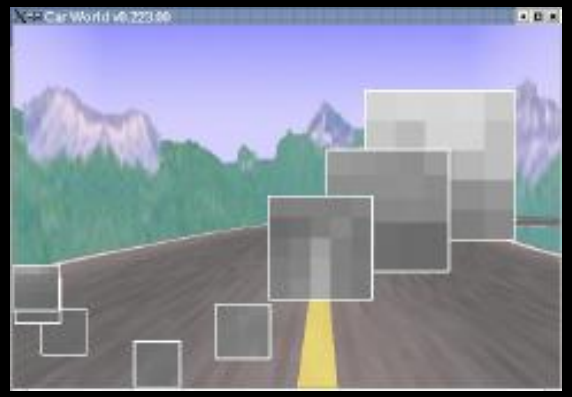
Related Research

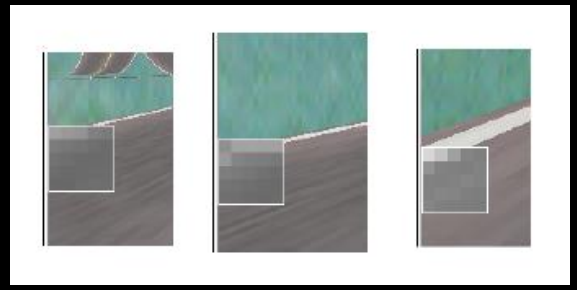
Koala robot obstacle avoidance (Marocco et al.)

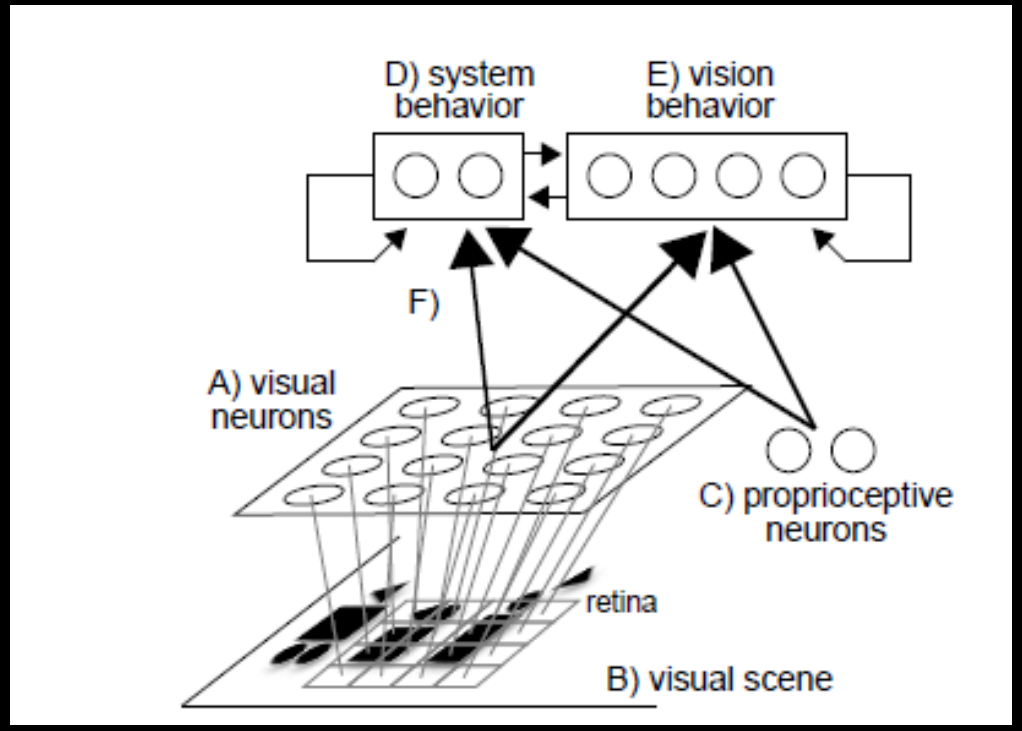


Related Research

Autonomous driving car (Floreano et al.)

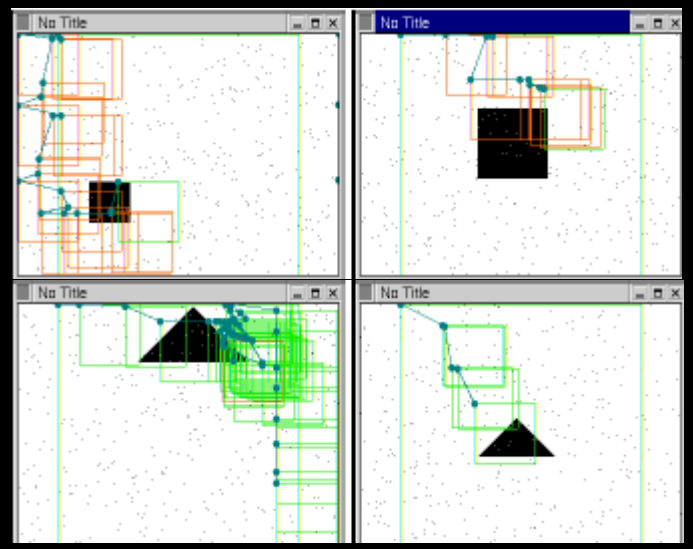


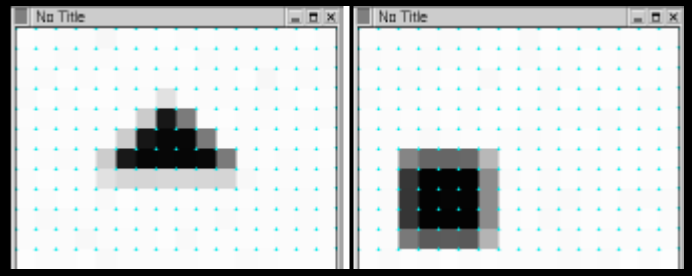




Related Research

Object recognition (Floreano et al.)





Going Further

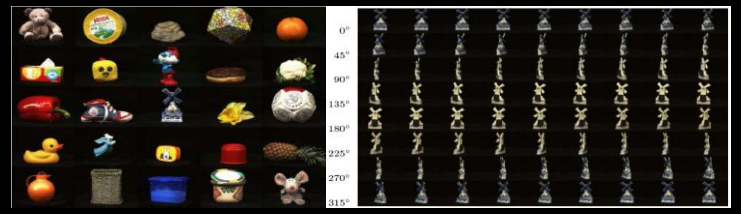
Designing active vision system for real-world object recognition

Task

Design active vision system that can learn to recognize the following objects

Method

- **Evolution of the active vision system for real-world object recognition**
  - training the system in a parallel manner on multiple objects viewed from many different angles and under different lighting conditions
- **Amsterdam Library of Object Images (ALOI)**
  - provides a color image collection of one-thousand small objects
  - recorded for scientific purposes
  - systematically varied viewing angle, illumination angle, and illumination color



- **Active Vision Training**
  - trained on a set of objects from the ALOI library
  - each genotype is evaluated during multiple trials with different randomly rotated objects and under varying lighting conditions
  - evolutionary pressure provided by a fitness function that evaluates overall success or failure of the object classification
  - trained on increasingly larger number of objects
- **Active Vision Testing**
  - robustness and resiliency of recognition of the dataset
  - generalization to previously unseen instances of the learned objects

Experimental Setup

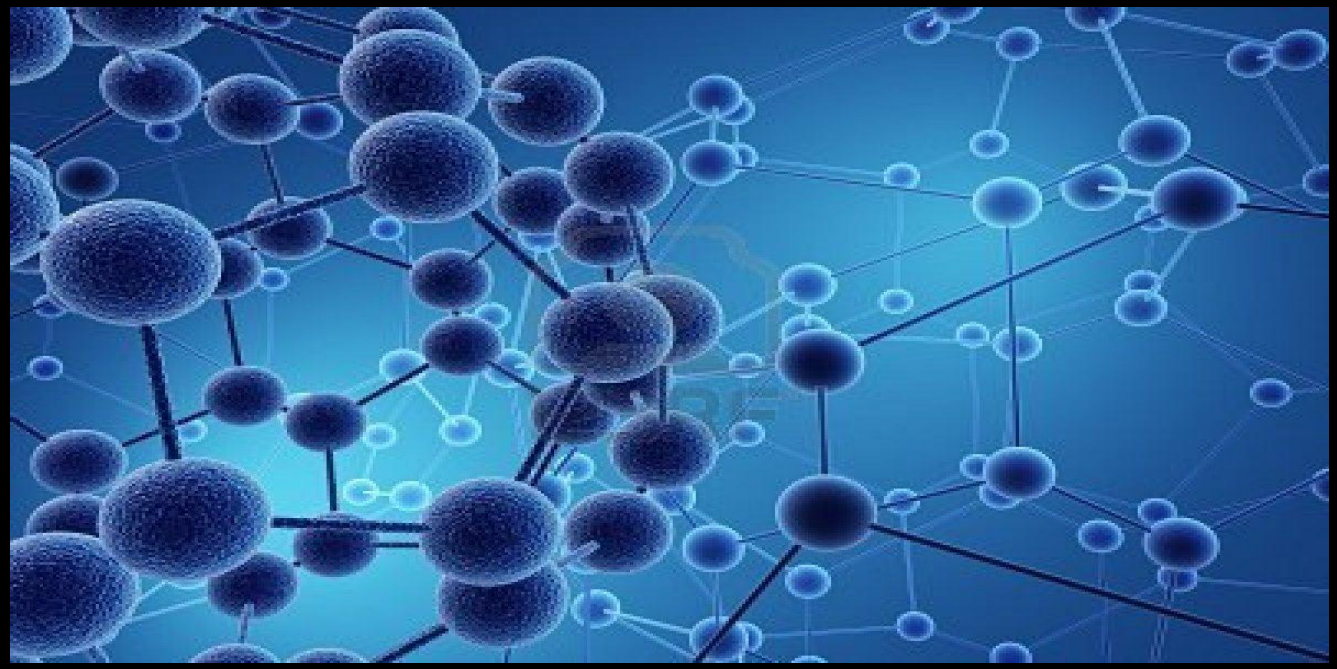
- Recurrent Neural Network
  - Inputs: 8x8 neurons for retina, 2 neurons for proprioception (x,y pos)
  - No hidden neurons
  - Outputs: 5 object recognition neurons, 2 neurons to move retina (16px max)
- Genetic Algorithm
  - Generations: 10000
  - Number of individuals: 100
  - Number of trials: 36+16 (object rotations + varying lighting conditions)
  - Mutation probability: 10%
  - Reproduction: best 20% of individuals create new population
  - Elitism used (best individual is preserved)

Experimental Setup

- Each individual (neural network) could freely move the retina and read the input from the source image (128x128) for 20 steps
- At each step, neural network controlled the behavior of the system (retina position) and provide recognition output
- The recognition output neuron with the highest activation was considered the network's guess about what the object was
  - Fitness function = number of correct answers / number of total steps

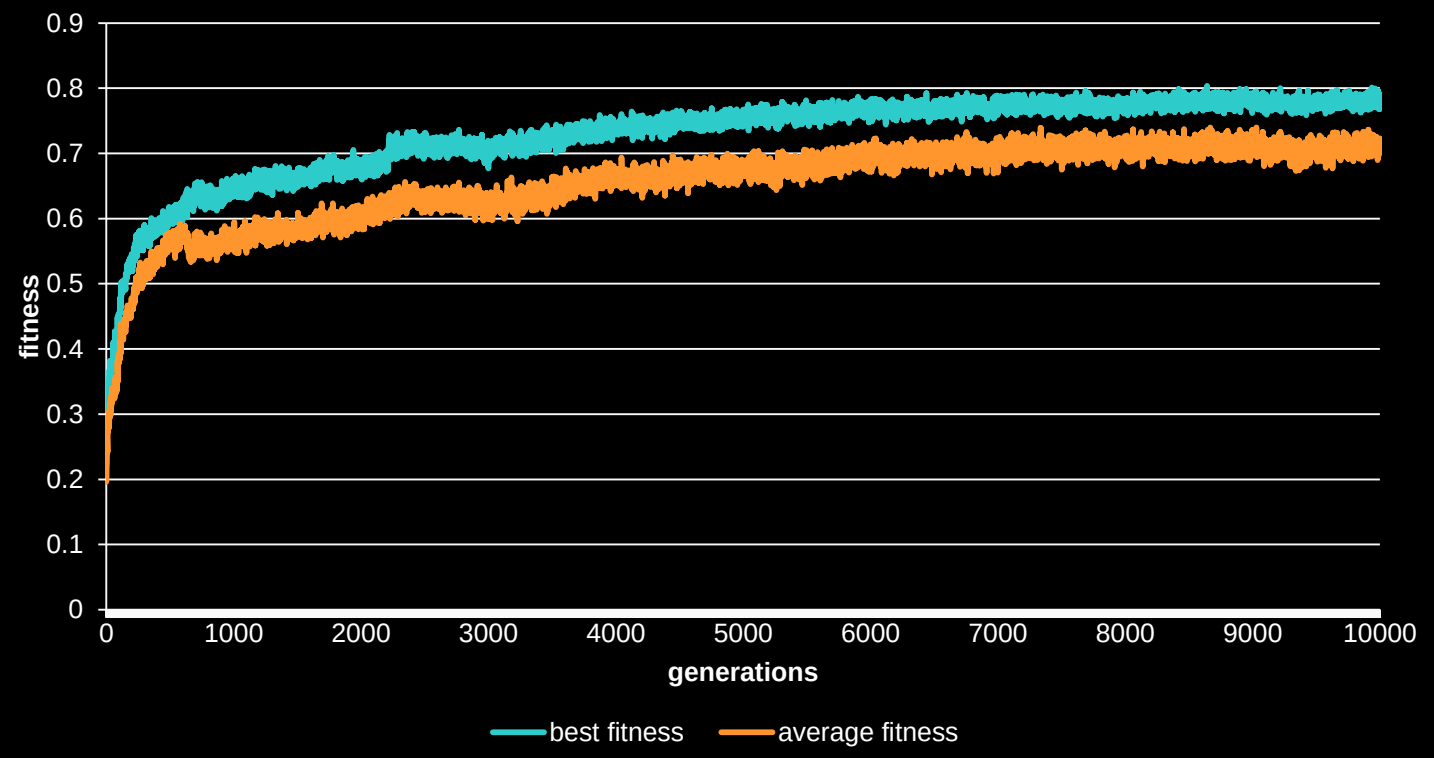
GPU Accelerating GA and ANN

- **GPUs were used to accelerate:**
  - **Evolutionary process – parallel execution of trials**
  - **Neural Network – parallel calculation of neural activities**



Results

- Fitness can not reach 1.0 since it takes few time-steps to recognize an object
- All objects are correctly classified at the end of the each test

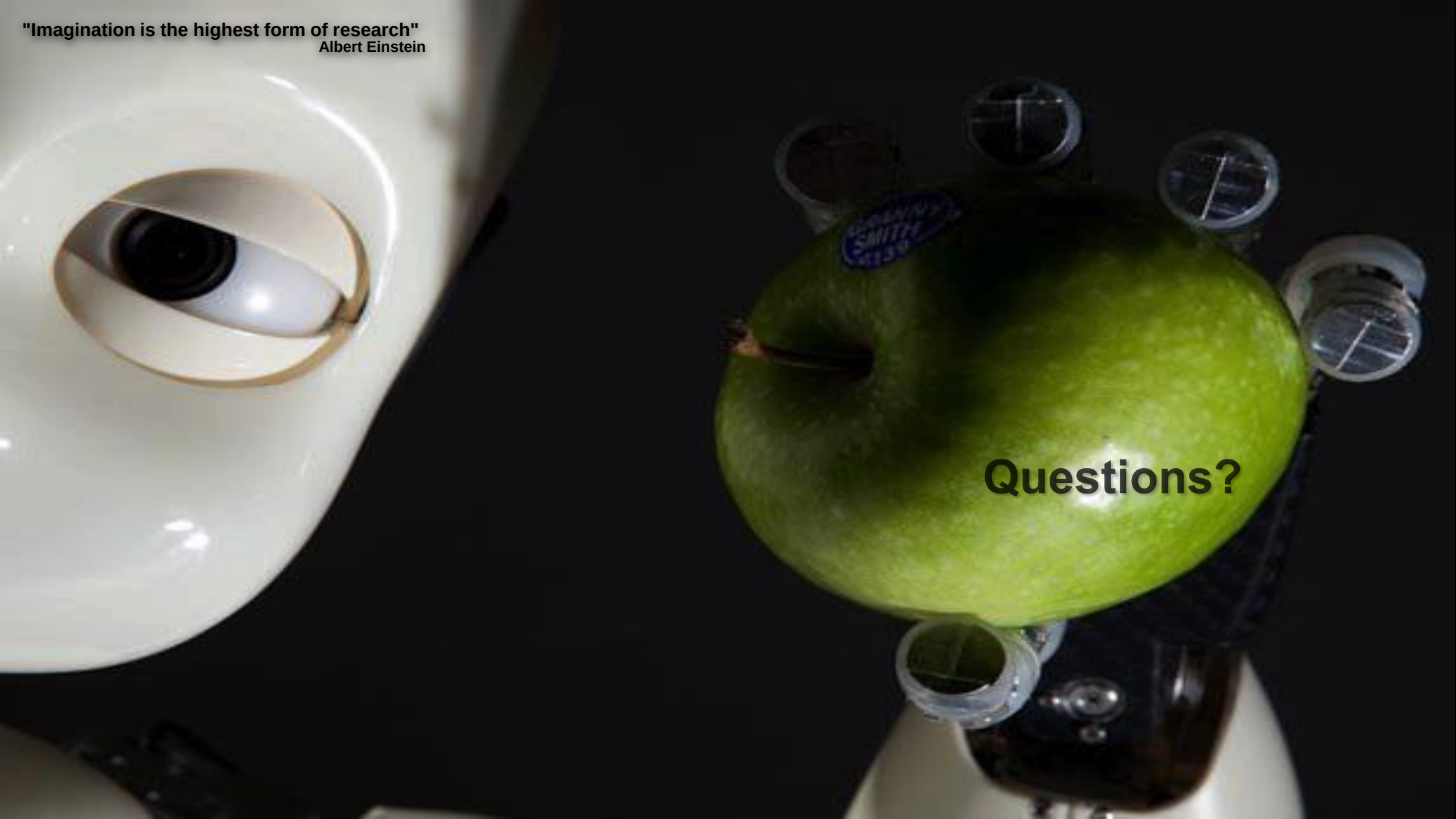


Evolved Behavior

Future Work

- Extending the current system and applying it to the real-world problems requiring fast and energy-efficient pattern recognition
- Implementing island model GA on GPU
- AXA Research Fund
  - Active Vision in search and rescue scenarios

"Imagination is the highest form of research"
Albert Einstein



Questions?