EVOLUTIONARY ROBOTICS:

THE ROLE OF GENE DUPLICATION AND MODULARITY IN THE EMERGENCE OF EVOLVABILITY

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Narration

INTRODUCTION

WHY EVOLVE ROBOTS?

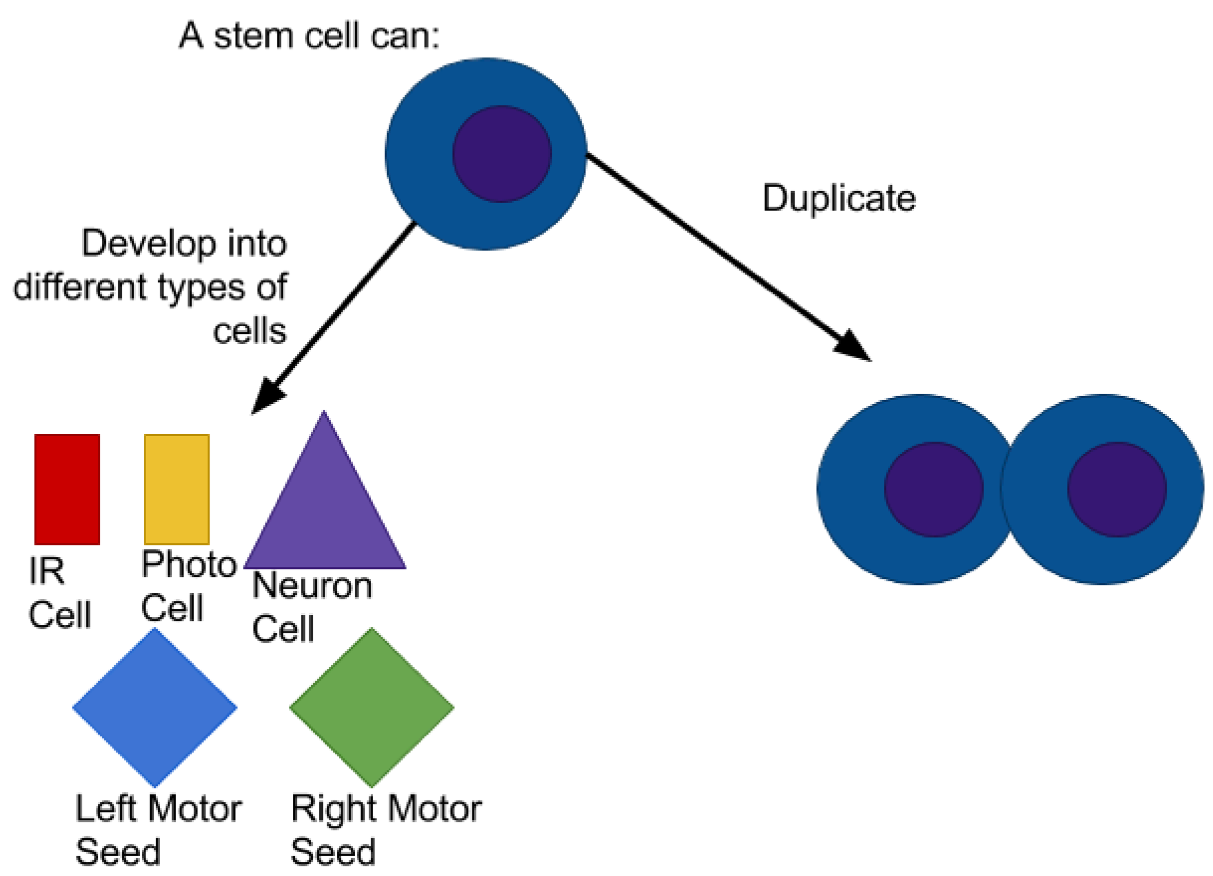
Evolutionary robotics takes a complex world and simplifies it to include only what is relevant to the question. This allows us to manipulate variables in ways that are not easily achievable with biological organisms.

THE HYPOTHESIS

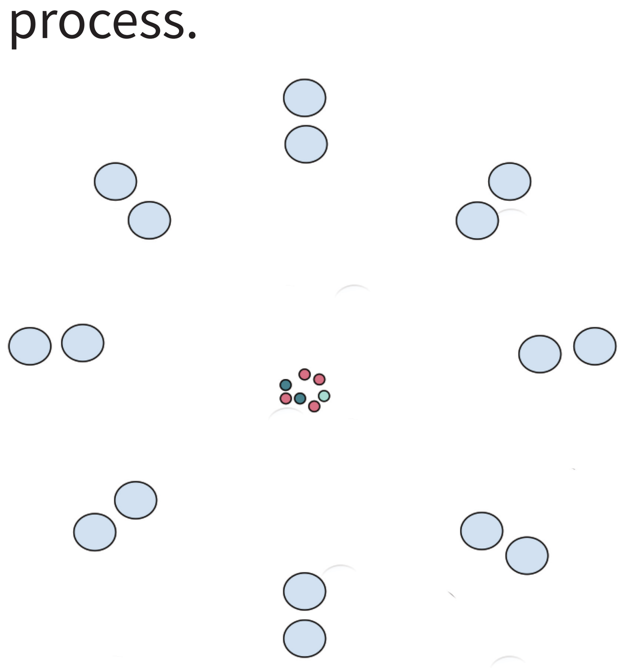
We hypothesize that mechanisms of gene duplication and subsequent differentiation increase the modularity of a robotic agent's sensor/neural network/motor system over generational time, resulting in populations that are more evolvable, that is, better able to survive and even prosper when fitness landscapes shift.

THE GENOTYPE-PHENOTYPE MAPPING SYSTEM

Evolutionary robotics experiments require decisions about how an artificial genome will specify the construction of the robot phenotype. This is typically done with a set of "build rules," which are brittle and do not handle gene duplication/deletion well.



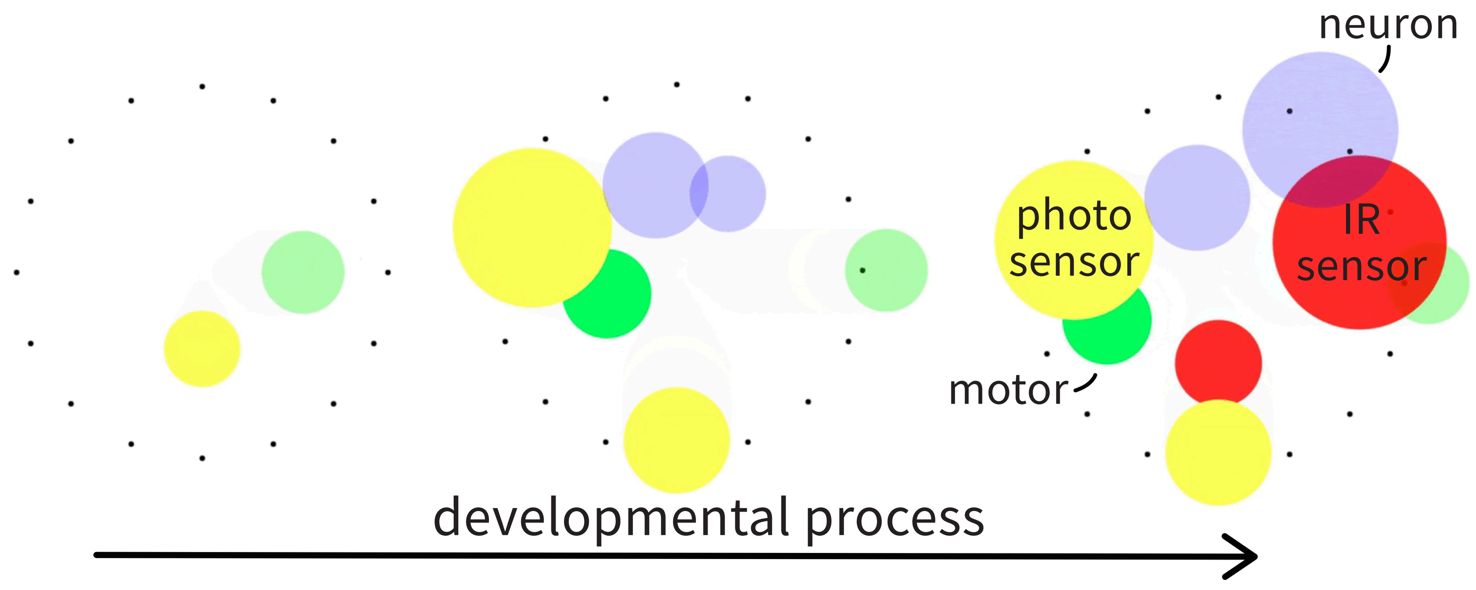
The Landro robot's G-P mapping system is inspired by the biological stem cell creation and differentiation process.



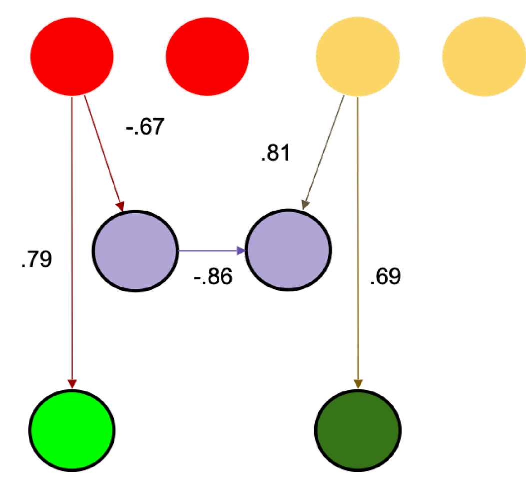
The genome specifies the "seeds" of "cells" (sensors, motors and neurons), shown in the center of the circle, which "grow" out through the development process and determine the phenotype.

A landro has 16 sensor positions, shown as the outer circles. Sensor activation occurs when the appropriate sensor "cell" touches an outer circle during development.

THE GENOTYPE-PHENOTYPE MAPPING SYSTEM (CONT.)

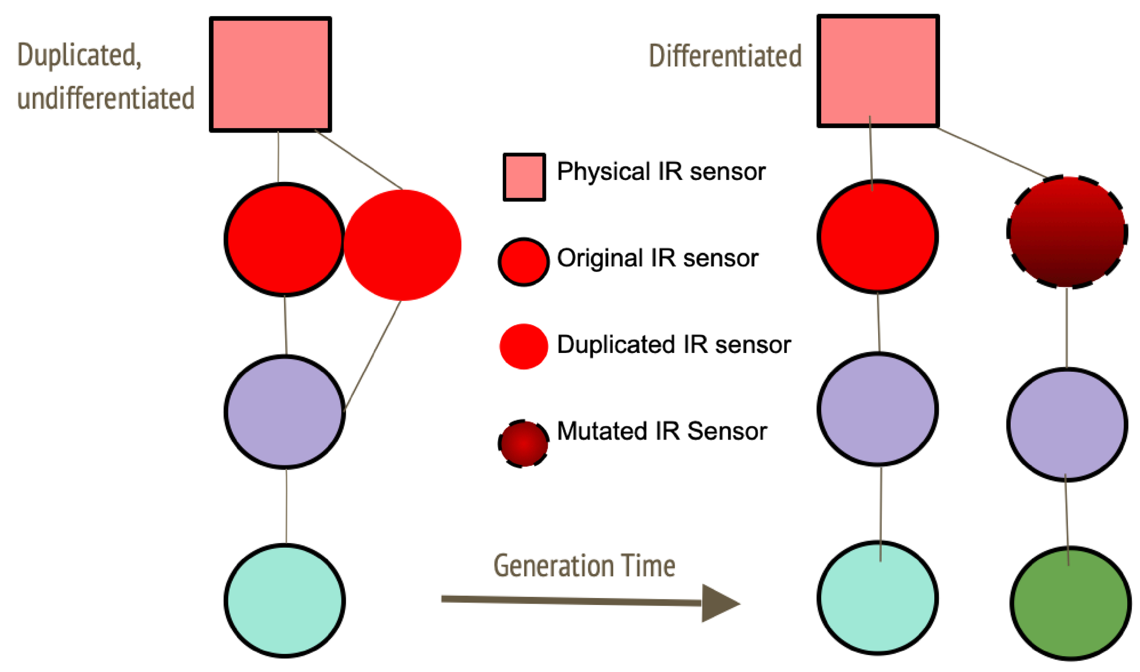


The genotype specifies the growth of a number of genes, which grow according to the start/end time, growth rate and angle specified by the genome. The figure to the left visualizes the growth process.



The finished phenotype is translated into a neural network as shown to the right, with active sensors, connections and their weights determined by how the "cells" interacted during the developmental process.

GENE DUPLICATION

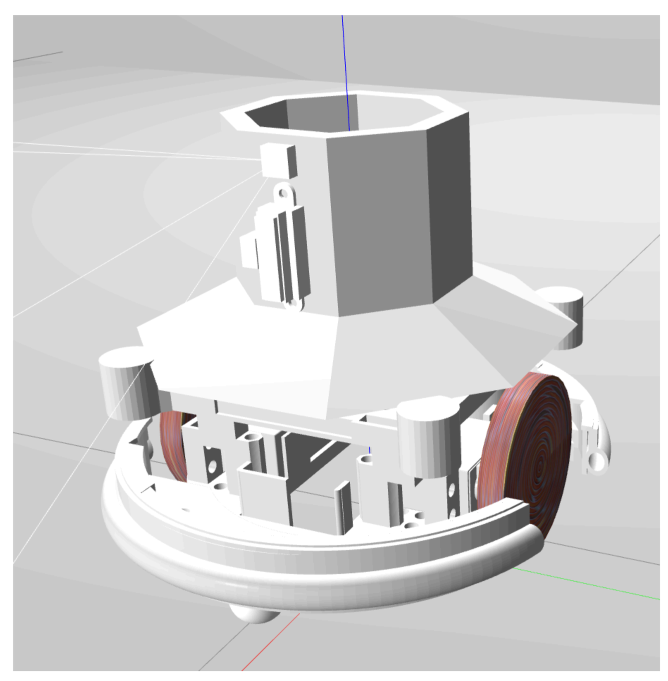


The network on the left shows the result of an IR sensor duplication in the genome. The physical sensor feeds information to two IR sensor "cells." Over time, the mutant duplicate becomes differentiated from the original, and has opportunity to make novel connections.

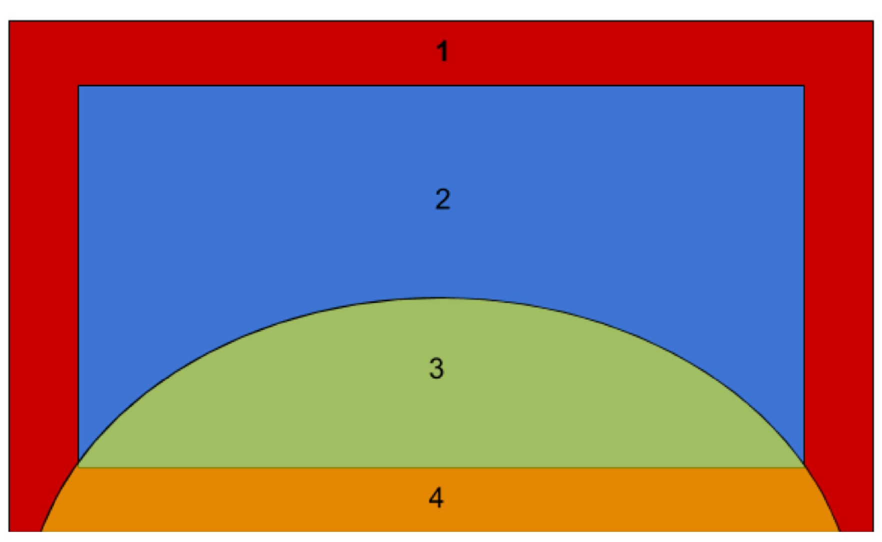
This is the mechanism hypothesized to produce increases in modularity, which we hypothesize will in turn increase evolvability.

ROBOT DESIGN

The physical Landro design consists of an octagonal sensor ring on top of a platform with one wheel on each side. The sensor ring houses 8 IR distance sensors on its lower portion, and 8 ambient light level photosensors on is upper portion. This sensor ring allows a degree of morphological variation: sensors activate only if they are specified by the phenotype neural network (sensors must both be created in the network and connected to another node to be activated).



X-OR ENVIRONMENT



The final element of the experiment concerns the nature of the environment within which evolution is explored. Because the X-OR problem is known to require networks more complex than those found in simple Braitenberg systems, we have constructed an environment in which information from two sensor domains is required to solve an X-OR problem.

There are two types of sensors: distance and light level.

With walls surrounding the four corners of the world and a lamp at one of the edges, we can separate 4 logical regions: (1) low distance/low light, (2) high distance/low light, (3) high distance/high light, (4) low distance/high light.

The robot receives positive fitness scores for time spent between regions (1) and (3), but not (2) or (4). This guides it to produce more complex behavior than "seek light" or "seek wall."