Robots in Biology

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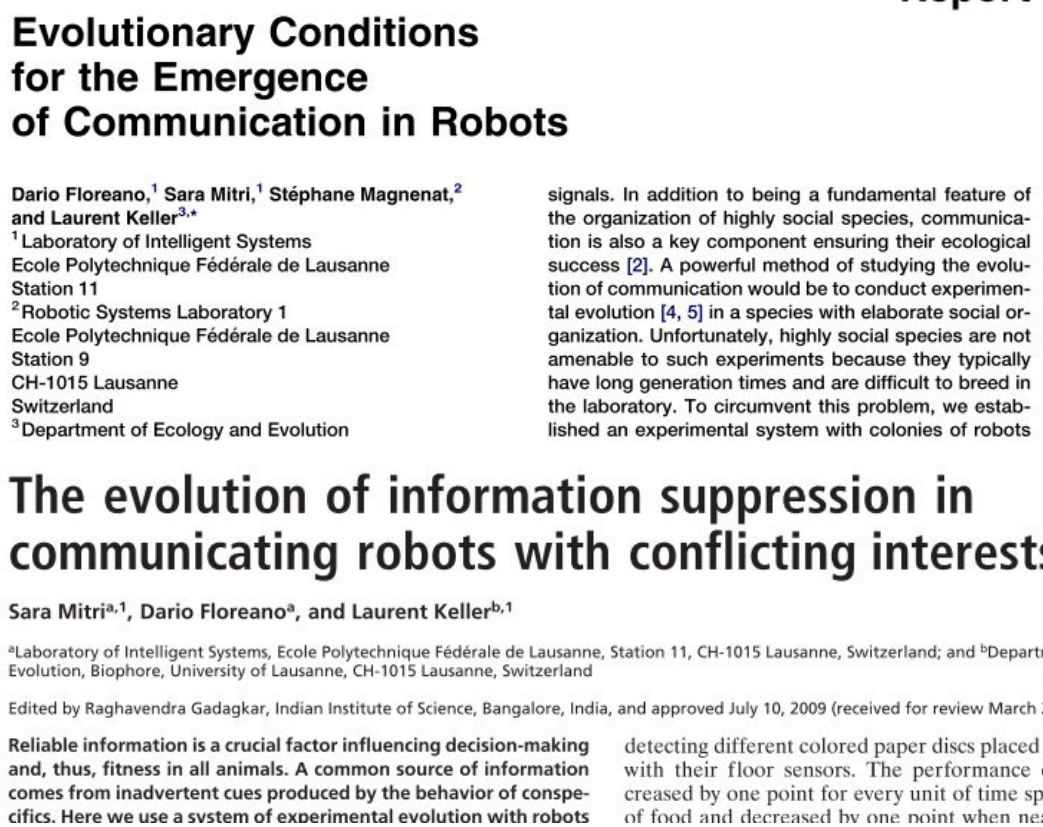
Studying Evolution with Robots



Report

Evolutionary Conditions for the Emergence of Communication in Robots

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signals. In addition to being a fundamental feature of the organization of highly social species, communication is also a key component ensuring their ecological success [2]. A powerful method of studying the evolution of communication would be to conduct experimental evolution [4, 5] in a species with elaborate social organization. Unfortunately, highly social species are not amenable to such experiments because they typically have long generation times and are difficult to breed in the laboratory. To circumvent this problem, we established an experimental system with colonies of robots

The evolution of information suppression in communicating robots with conflicting interests

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Reliable information is a crucial factor influencing decision-making and, thus, fitness in all animals. A common source of information comes from inadvertent cues produced by the behavior of conspecifics. Here we use a system of experimental evolution with robots

detecting different colored paper discs placed und
with their floor sensors. The performance of r
creased by one point for every unit of time spent
of food and decreased by one point when near p

- **Robots have demonstrated**
  - the evolution of **altruism (Hamilton's Rule)**
  - Evolution of **communication suppression**
  - Evolution of **communication**

Why use Robots?

- Alternatives are computer simulations that can mimic the physical movements of robots and produce the same results.
  - Evolution of Communication
  - Evolution of Group Behavior
- Yes: The robots are not merely representing evolution, they are evolving and should be the subject of study
- No: Robots merely represent ideas, and anything that does the same can easily replace them
  - Studies often choose to conduct both physical robot experiments and robot simulations to gather data

Case Study 1: Evolution of Coordinated Group Behavior

- Insects display an advanced form of coordinated task partitioning, and robots were used to study the evolution of this behavior.
- By selecting for robots that performed well in environments that encourage collaboration, the robots were able to evolve division of labor from primitive commands
  - Grammatical Evolution

Grammatical Evolution

The individual behavior of a given robot was expressed by a set $\mathcal{R}$ composed of an arbitrary number n_R of *rules* R_i:

$$\mathcal{R} = \{R_i\}, i \in \{1, \ldots, n_R\}.$$

Each rule was composed of three components:

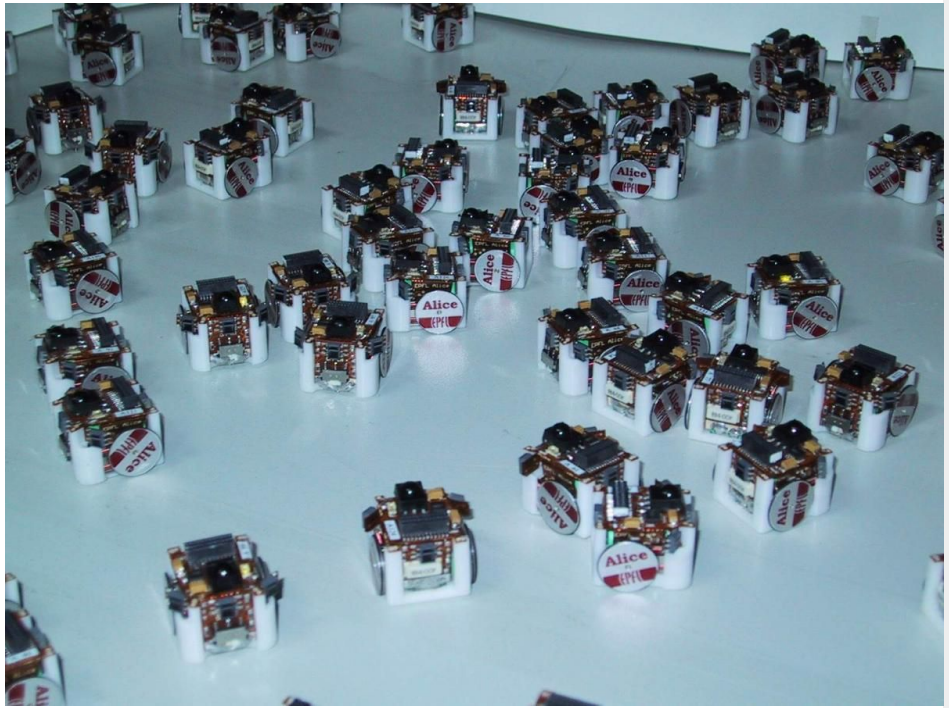
$$R_i = \mathcal{P}_i \times \mathcal{B}_i \times \mathcal{A}_i,$$

B_i = subset of all possible behavioral building blocks (movement in response to light signals and random walking)

A_i= subset of all possible actions (dropping objects, picking them up)

P_i= preconditions (Sensory input and internal state variables)

Testing Hamilton's Rule with ALICE



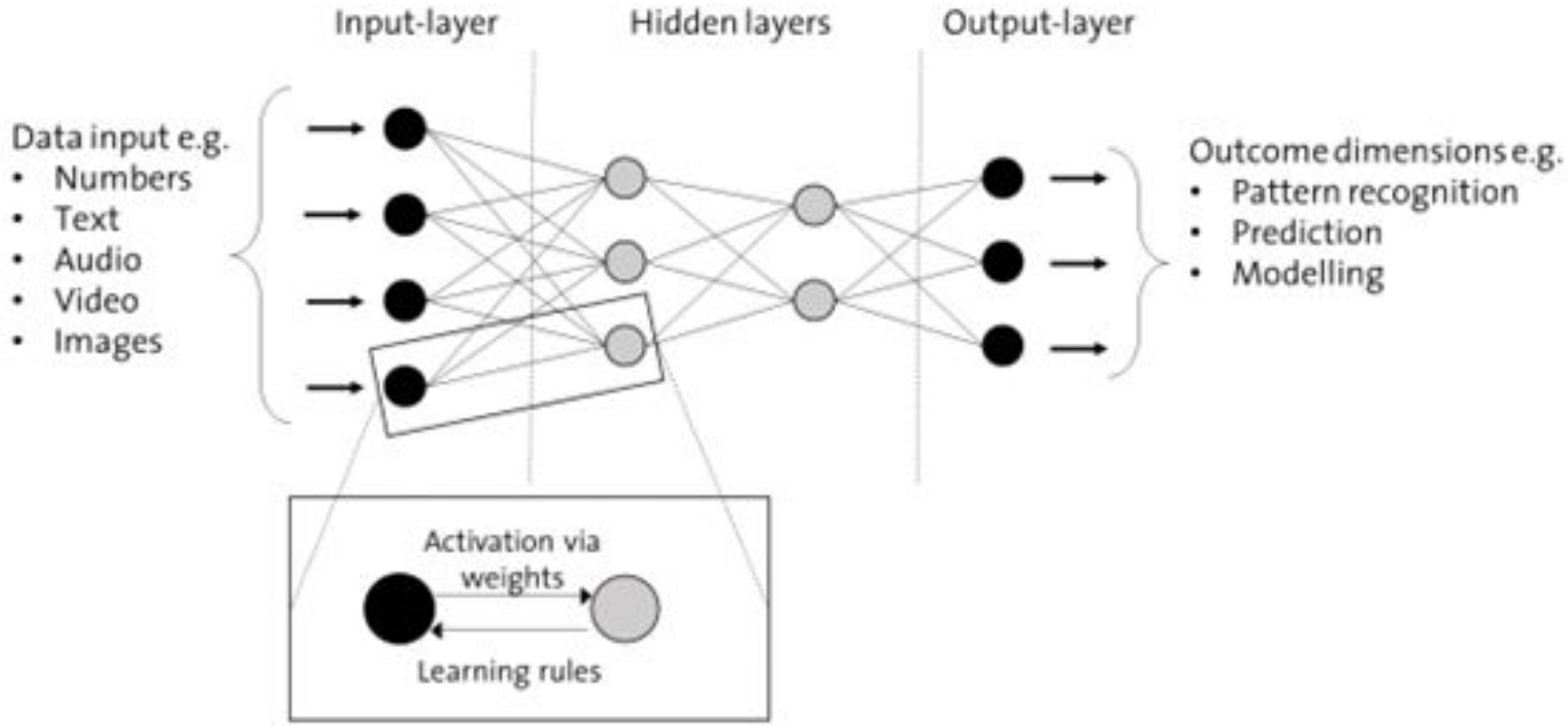
- **Hamilton's Rule:** Altruistic behavior can confer a fitness benefit by increases that chances that the genes of kin are passed on
- Robots in an arena competed for food, and **either 'consumed' it or 'shared' it.**

The Neural Network and ‘Artificial Genome’

-ALICE had a neural network that consisted of 13 ‘neurons’ that formed 33 connections

-The weight of each connection was governed by 33 genes (parts of software) that enabled their complex behavior.

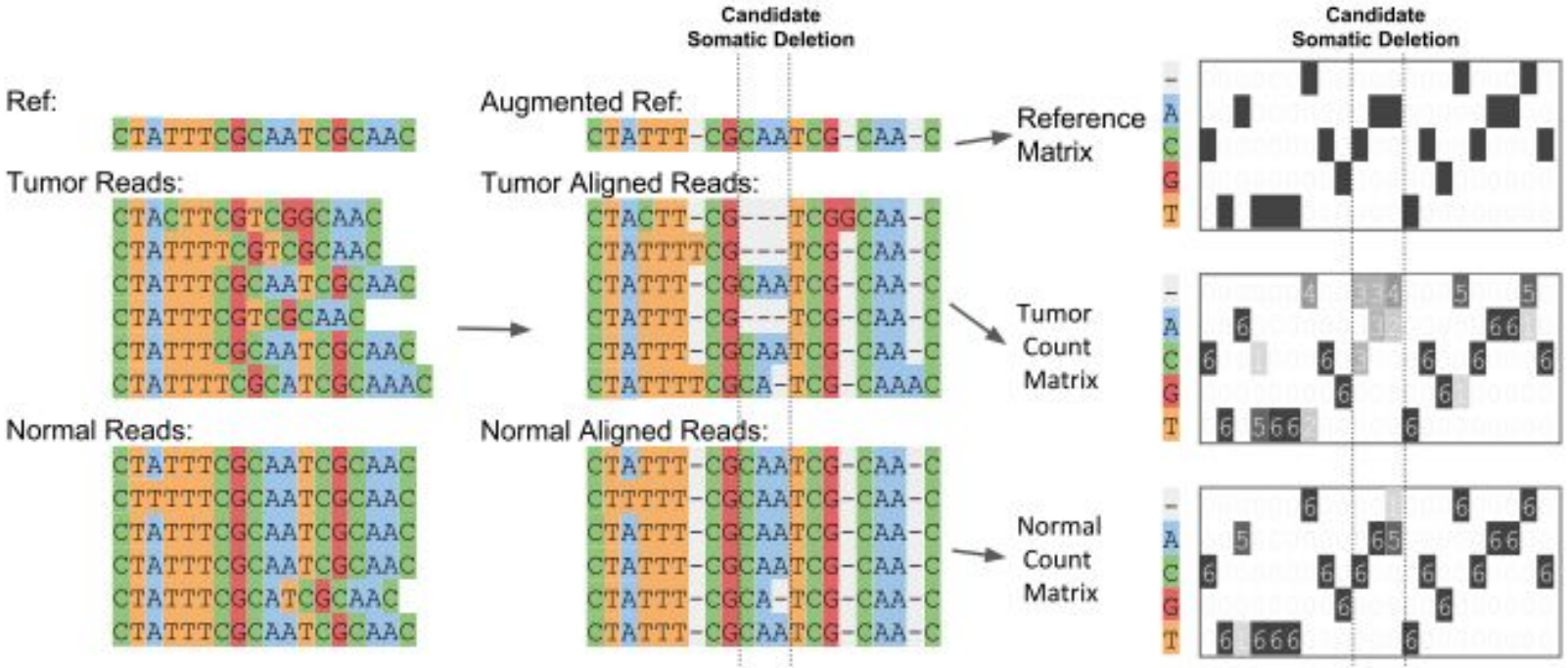
Artificial Neural Networks



Molecular Biology: Detecting Somatic Mutations

- Detecting mutations in DNA helps us understand diseases
- There are several challenges that exist in achieving mutation detection with high accuracy:
  - False positives
  - Background errors
- Older deep learning attempts learn ‘feature representations’ directly from raw data using patterns seen in local regions in the genome.

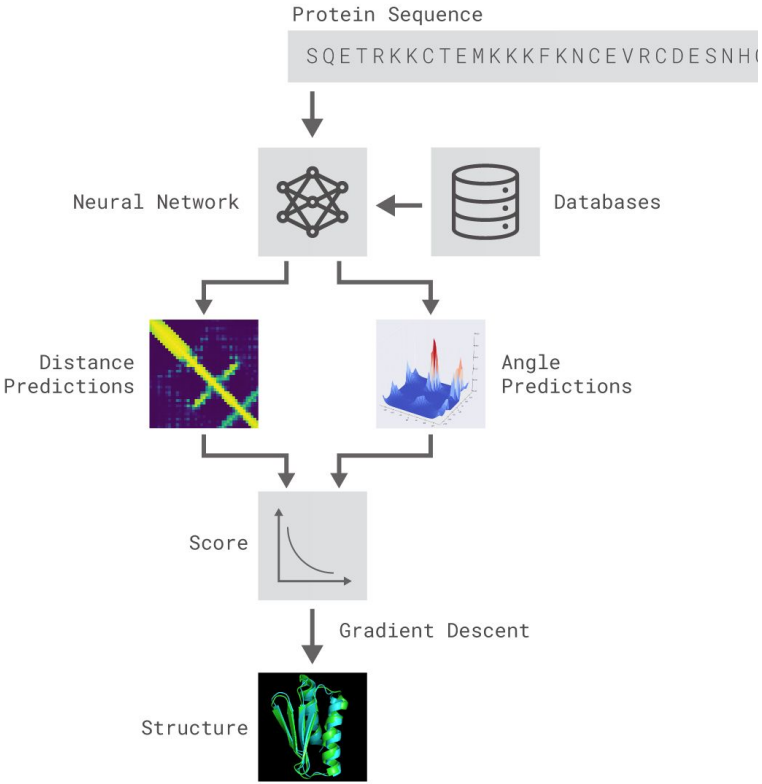
NeuSomatic: Convoluted Neural Network Based Mutation Detection



Predicting protein structure

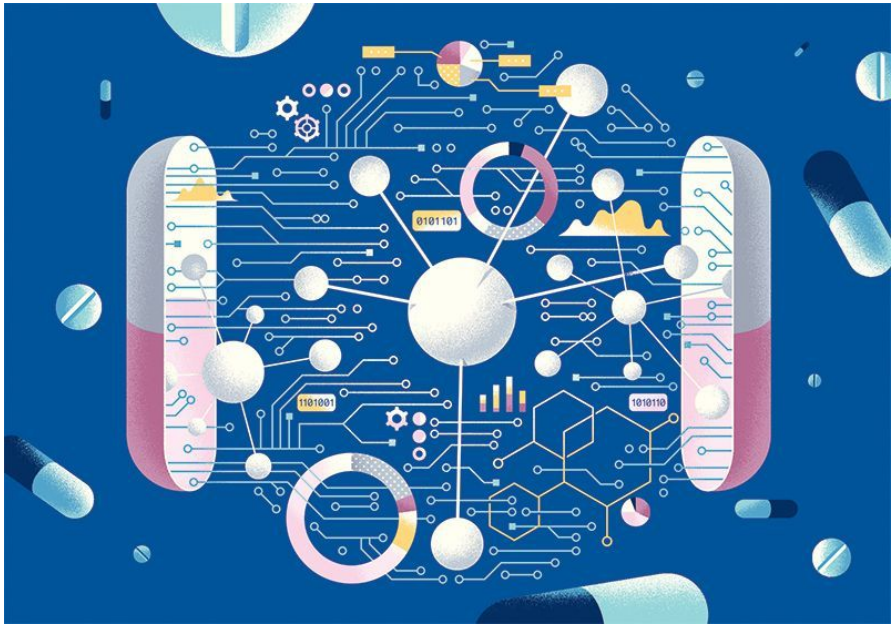
- Predicting a proteins structure would improve our understanding of the body, enabling scientists to design new, effective cures for diseases caused by misfolded proteins more efficiently.
- The 3D models of proteins that AlphaFold generates are far more accurate than any that have come before

How does AlphaFold work?



- **Artificial neural networks** predict distances between amino acids and the angles between the bonds that connect these amino acids
- The probabilities of each prediction were combined into a score to estimate the accuracy of the proposed structure
- The score was optimised using **gradient descent**

AI aided drug discovery



- DeepGenomics, founded in 2015
- Aims to create personally tailored genetic medicine by utilizing AI to determine how DNA variations produce specific diseases
- Uses data from DNA sequences and cell variables to train a neural network
- Preselects target molecules to eventually test in the lab

Neuroscience informs the development of AI

- Brain-like computations like neural networks and reinforcement learning methods have been combined in AI algorithms to produce AI that are able to imitate the way humans approach problems
  - AlphaGo
- With large research efforts being invested in future AI applications, a major question is the degree to which current approaches will be able to produce human-like understanding
- Current AI models rely on large sets of training data to learn
- Humans accomplish complex behavioral tasks with limited training, relying on pre-existing network structures already encoded in the brain
- Useful pre-existing structures could be adopted into AI models to make them more human-like

Thank You!