DCC's Project: The Idiotypic Network

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Summary

Introduction

Our approach

Our approach basically consisted to:

- define the specific domain;
- extrapolate the domain's necessary information;
- correctly define the agents;
- proceed with the *Java Repast Symphony* implementation.

Some problems...

The main obstacles we encountered were:

- a very unfamiliar domain;
- how to interpret the information in the correct way;
- getting into agent-based programming.

The Immune System

What is the Immune System?

Any kind of organism is constantly exposed to external pathogens which can potentially harm the organism itself. The immune system offers a natural barrier: its main task is to *prevent and limit infections*.

How it operates?

The immune system activates certain cells and proteins to fight against these invading microorganisms. It operates according to two main phases:

1. pathogen identification;
2. appropriate response to the problem.

How is structured?

The entire immune system can be broken down into two categories:

1. *innate immune system*;
2. *adaptive immune system*

Innate Immunity

The concept of innate immunity is associated with the innate immune system:

- present form birth;
- result of a long term evolution;
- non-specific.

Adaptive Immunity

The term adaptive immunity is instead used in reference to the adaptive immune system:

- created during life;
- result of a continuous exposure to external substances;
- highly-specific.

Role of the adaptive immune system

The adaptive immune system is concerned with the production of specific cells or antibodies that destroy a particular antigen.
We simply define the antigen as something external and potentially harmful to the immune system.

Adaptive Immune System Cells

As a whole, the adaptive immune system is composed of lymphocytes and the antibodies that are produced by them. We have two different types of lymphocytes:

- *T lymphocytes*;
- *B lymphocytes*.

Immunological memory

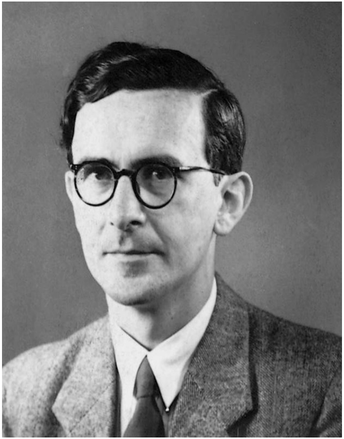
Cells remember exposure to a pathogen over time by building an immunological memory. When confronted with an unrecognized pathogen, the immune system:

1. responds with a first mild reaction;
2. the cells memorize the exposure;
3. during the next exposure the immune response will be stronger.

The Parisi's model

The Immune Network Theory

The functioning of the adaptive immune system can be seen through the *Immune Network Theory*, conceived in 1974 by Niels Kaj Jerne.
The Immune Network Theory states that the production of antibodies, following an external antigen, can be seen as a chain phenomenon.



Parisi's intuition

Based on Jerne's studies, Parisi recognized that it would be possible to formalize this concept. He decided to build a simple theoretical framework based on it to derive results analitically.

The goals of the model

In *A simple model for the immune network* Parisi wanted to describe the evolution of the network without the internal presence of any antigen. His focus points were:

1. the immune system's behaviour;
2. the immunologic memory's evolution.

The needed assumptions

In order to describe the network, Parisi defined a set of assumptions:

- there is a large set of low responder clones;
- the model itself can be seen as a unique entity with a high connectivity;
- the immunological memory is a shared property.

The model formalization

Although other models were conceived, the Parisi one was specifically designed to be as simple as possible.

Parisi's model

$$h_i(t) = S + \sum_{k=1}^{N} J_{i,k} c_k(t) \tag{1}$$

- $h_i(t)$: the stimulatory or inhibitory effect of the network on the antibody i at time t;
- $J \in R^{n \times n}$: the influence of the antibody k on the antibody i.

The model formalization

Parisi's model

$$c_i(t+\tau) = \theta[h_i(t)] \tag{2}$$

- $c_i(t)$ of the concentrations of the possible antibodies;
- τ: discretized time of about one week, that corresponds to the average immune response time.

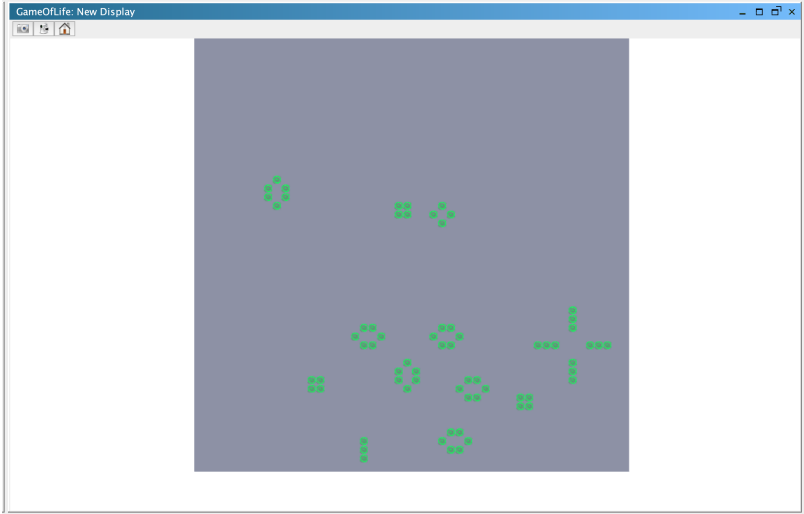
Parisi's model

We define θ of the previous Equation (2) as:

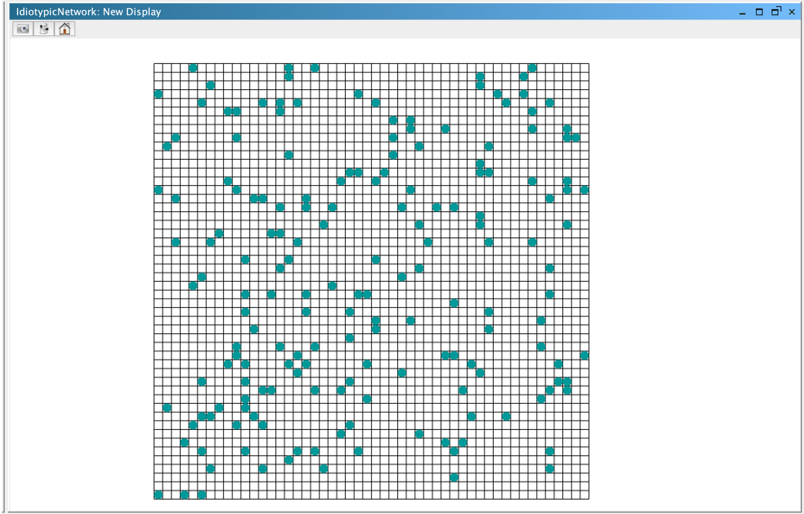
$$\theta(x) = \begin{cases} 0 & \textit{if} \quad x < 0 \\ 1 & \textit{if} \quad x \geq 0 \end{cases} \tag{3}$$

How we proceeded

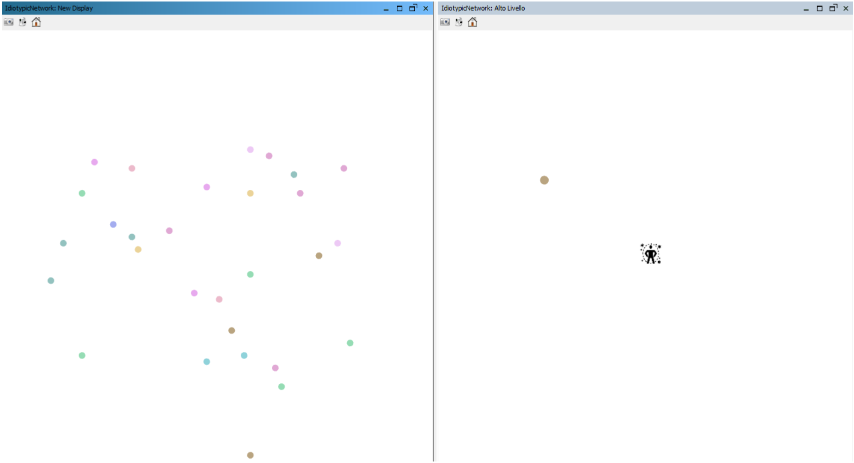
Game of Life



First Idiotypic Network implementation



Final Idiotypic Network implementation



Implementation

Two levels of abstraction

In our implementation we took into account two levels of abstraction:

1. **Low-level implementation**: consist of the idiotypic network with *Antibody* as the agent and the *Immune System* as environment;
2. **High-level implementation**: the *Immune System* becomes a reactive agent towards an external *Antigen*.

List of agents

Antibody

Immune System

Antigen

External agent

Antibody

The *Antibody* is the most basic agent. It is characterized by:

- a type;
- a value that we will call *hValue*;
- the possibility of being alive or dead;
- the possibility of being in equilibrium or not (calculated by the *EquilibriumDataStructure*).

Each *Antibody* affects the others by updating their *hValue* and changing its state from alive to dead or vice versa.

Immune System

We can see the *Immune System* at two levels:

Low-level implementation:

- it randomly generates the matrix between antibodies;
- it checks if each antibody is in equilibrium or not.

High-level implementation:

- it reacts to the presence of an antigen of a certain type;
- if the antigen is unknown, it creates a specific antibody.

Antigen

The *Antigen* is the external threat and:

- it consists of a type;
- it moves near the *Immune System*;
- it causes the reaction of the *Immune System*.

As a whole, *Antigen* can be viewed as a triggering process.

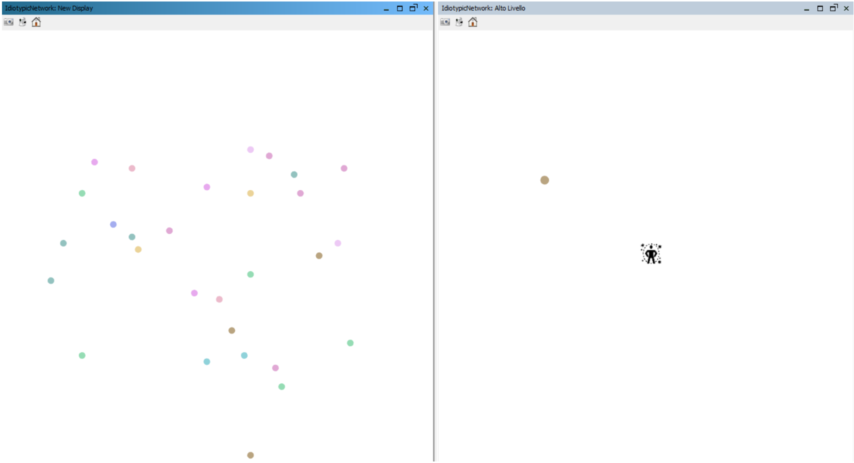
External Agent

The *External Agent* is fully entered for simulation purposes:

- it randomly creates a new *Antigen*;
- it checks that the *Immune System* is being attacked by only one antigen at a time.

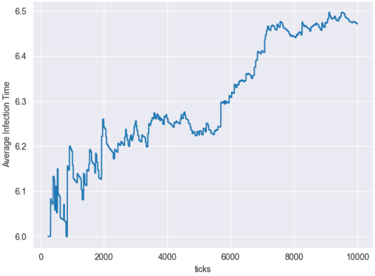
Simulation 1

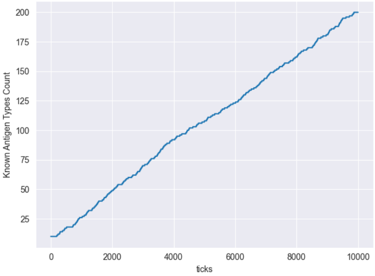
Simulation


IdiotypicNetwork: New Display
IdiotypicNetwork: Alto Livello

Collected data

The model provides a dataset too, to acquire data to study this phenomenon from the simulations.





Conclusions