Logical Approaches

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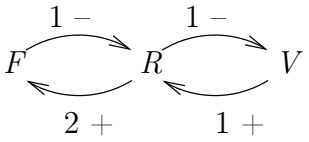
Workshop designed with the help of Houssine Snoussi

The running example

The Thomas discrete theory has been designed for gene networks but it can be applied to any interaction network where the existence of action thresholds is credible. Here, a cultivated field is invaded by rabbits, which is harmful to the vegetables of this field... but foxes begin to be interested... Let us study the qualitative dynamics of this system.

The population of foxes (F) has a negative effect on the population of rabbits (R) as foxes are predators of rabbits. In return, rabbits have a positive action on the population of foxes as they nourish foxes. Similarly, the rabbit population has a negative effect on the population of cultivated vegetables (V) and, in return, the vegetables nourish rabbits.
We assume here that more rabbits are needed to help the population of foxes to grow than to reduce the quantity of vegetables in the field. So the action of rabbits starts at threshold 1 on vegetables and it starts at threshold 2 on foxes.



Static analysis

According to the abstract description of interactions between F, R and V:

1. What are the possible discrete expression levels for each variable F, R and V according to the theory of René Thomas?
2. How many discrete parameters are necessary to model this network?
3. Fill in the table of ressources (i.e., the set of ressources of a variable for a given discrete state of the network).

F	R	V	ressources of F	ressources of R	ressources of V
0	0	0	...	...	...
0	0	1	...	...	...
0	1	0	...	...	...
0	1	1	...	...	...
0	2	0	...	...	...
0	2	1	...	...	...
1	0	0	...	...	...
1	0	1	...	...	...
1	1	0	...	...	...
1	1	1	...	...	...
1	2	0	...	...	...
1	2	1	...	...	...

Hand made identification of parameters

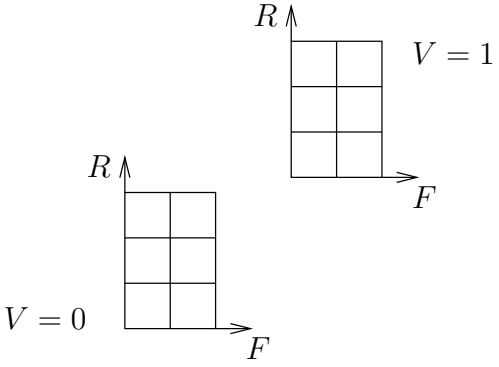
In this example, the Snoussi condition is clearly satisfied and the farmer has also made the following observations:

1. For each species (F, R or V), there exist conditions on the two other species such that the considered species can reach its minimum (0) and there also exist conditions such that it can reach its maximum (the bound of the variable).
2. In the past, before the foxes come, the populations of rabbits and plants were oscillating.
3. He has also tried to artificially maintain a high population of foxes for a sufficiently long time: In these conditions, an oscillation of the populations of rabbits and plants is also observed.
4. Lastly, if both populations F and V are artificially maintained high, when $R = 2$ it decreases ($R < 2$).

Indeed, these four observations are sufficient to deduce the parameter values of the network.

Let's do it!

Lastly, let us draw the transition graph according to the deduced parameter values, using a 3D shape like this one:



Symbolic AI identification of parameters: TotemBioNet

Observed properties are expressed as formulas according to a *temporal logic* called "Computation Tree Logic", everything is then automatically deduced by the computer.