into the ecosystem. (Ignore the details of the neighbour population in terms it becoming smaller due to individuals leaving).

When simulating the model, run a simulation in which the *Number_of* starts at *Zero*. This should result in a state-graph in which this population starts growing from *Zero* and reaches it maximum size. Also run a simulation in which *Number_of* starts at a value higher than *Zero*. Does this situation lead to the population becoming extinct (thus *Number_of* going to *Zero*)? Why not? An additional assignment could be to adapt the model such that it does go to *Zero*, e.g. by including an emigration process.

Negative, Neutral and Positive growth

This assignment is intended to get the reader acquainted with the assumption mechanism in Garp3 (not to be confused with the notion of 'using assumptions', which refers to using additional labels to include or exclude model fragments). The assumption mechanism in Garp3 is always active. It is concerned with inequality reasoning. Particularly, in the situation that an inequality cannot be proven inconsistent, the engine 'assumes' that the inequality is true. This assumption stays active until counter evidence is found, in that case all inferences depending on the assumption are considered incorrect (which may lead to states not being generated).

The Garp3 engine assumption mechanism can be used to automatically try all possible values for quantities by creating model fragments with conditional value assignments for each value of such quantities. In this assignment this mechanism is used to generate all values for the quantity *Growth*. Proceed as follows:

- Use only one rate: the quantity *Growth* (and do not use *Birth*, *Death*, *Immigration* nor *Emigration*). *Growth* can take on three values: {min, zero, pos}, referring to decrease, steady and increase (notice that *zero* should be a point).
- Define a process (e.g. named 'Growth') in which the quantity *Growth* has a positive influence on *Number_of* (thus: when *Growth* has value *min*, *Number_of* will decrease, with value *zero* it will stay steady, and with value *plus* it will increase).
- Create three subtypes of this process model fragment, namely 'Negative growth', 'Neutral growth' (i.e., no change), and 'Positive growth'. Each of these fragments as a conditional value statement concerning *Growth*, namely *Growth<zero*, *Growth=zero*, and *Growth>zero*, respectively.

When simulating the model, run a simulation in which the *Number_of* starts at a value higher than *Zero*. Does *Number_of* go to *Zero* in this simulation? If not, why? Hint: is there feedback from *Number_of* on *Growth.* See also previous assignments.

B.3: Communicating Vessels

Construct a (simple) qualitative model that captures the typical behaviour of communicating vessels (also referred to as U-tube systems), using a QPT oriented approach.

Take the following details into account:
The height of the liquid column determines the pressure at the bottom of the container. The amount of liquid determines the height of the column. The latter also depends on the width of the column, but when the containers have the same shape this fact can be ignored (assume the containers are equal). When two containers are (partially) filled with liquid and connected by a pipe near the bottoms of the containers, the pressure difference (at the bottoms) between the two liquid columns determines the flow of liquid

between the two containers (via the pipe by which they are connected). The flow changes the amount of liquid in the containers. The container with the highest liquid column (and thus, the highest pressure), will loose liquid, whereas the amount of liquid in the other container will increase. The changes in the amount will eventually change the pressures at the bottoms of the two containers: they will become equal. That is, there is no pressure difference and thus no flow.

Proceed as follows

- Construct the model ingredients using paper + pencil.
- Define the expected states of behaviour and transitions. This is to illustrate how you think the simulator will simulate behaviour using your specifications.
- Implement the model using the Garp3 software. Your model should at least include:
    - A scenario with unequal liquid column heights.
    - A static model fragment describing the behaviour of a 'contained liquid' (the features of a container containing liquid).
    - A process model fragment describing a liquid flow process between two 'contained liquids'.
    - When simulating the model the unequal column heights should become equal in one of the successor states. Notice that the simplest model will only produce two states of behaviour, but more complex state-graphs are also possible.

B.4: Heating & Boiling

Construct a model of a heater that heats a container containing water. Different options exist:

- *Open or closed container:* The container can be open at the top allowing the water to evaporate without seriously affecting the pressure of the container. Or the container can be closed and heating causes the pressure inside the container to increase, which may lead to the container exploding.
- *Relative temperatures:* The temperature of the heater may differ with respect to the boiling point of the water. The temperature can be below, equal or higher compared to this boiling point.
- *Kind of heat source:* The heat source could be another object with a certain temperature and a certain amount of heat that exchanges energy with the container containing water. Alternatively, the heat source could be a kind ‘infinite’ resource (e.g. a furnace) that keeps on generating energy.

Sections 4.5 and 4.6 present both models with an open container. In Section 4.5 the heat source is considered an external and ‘endless’ source of energy with a temperature higher than the boiling point of the water. In Section 4.6 the heat source is considered an object with a finite amount of energy, while the relative temperatures are unknown (that is: all options are taken into account during simulation).