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BUILDING QUALITATIVE MODELS using Homer and VisiGarp

Assignment 2 – Pollution in a river

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There is a river. This river contains a food web and produces detritus. When dissolved nutrients in the water increase (due to pollution, for instance), changes in the food web will end up with the amount of dissolved oxygen decreasing. As a consequence, the fish population decreases.

Being more detailed, the idea here is that when the nutrients increase, plants do more photosynthesis and increase their mass. This will influence the fish biomass, which will also increase. Both plants and fishes will produce more detritus. With more organic material in the water, decomposers respiration will increase, resulting in dissolved oxygen decreasing. This will influence fish mortality, resulting in a decreasing amount of fish in the river. We could say that, as a 'rule', fish population follows available oxygen: if the amount of oxygen is high, fish population may be high as well, and when the amount of amount of oxygen is low, so is the fish population.

We want to build a model that shows us how changes in the amount of dissolved nutrients will affect the other objects (and quantities) in the system. This model will then support predictions such as: 'if nutrients increase, then the amount of oxygen decreases and the fishes also decrease'.

Specifications of the model

The river is seen as a container. Everything will happen within this container. In this sense, the river 'contains' all the objects (entities) mentioned in the model. The system consists of two types of biological entities: autotrophic organisms (plant) and heterotrophic organisms (fish and decomposers). We will model them as 'compartments' that represent the mass of that kind of organisms. Therefore, an entity called 'fish' included in the model represents all the fishes found in the river. The model will also represent the idea that 'fish eats plant'.

Each of these biological entities is associated with a quantity that represents their mass. The river also contains nutrients, oxygen, carbon dioxide and detritus. In order to reduce the complexity of the model, we are not representing them as entities, but as properties of the river. This way, they will be represented as quantities (variables). The model should therefore include the following quantities:

- mass (of plant, fish, decomposers)
- nutrient
- oxygen
- carbon dioxide
- detritus

We assume that all these quantities have the same qualitative representation of possible values. We will define their quantity space (QS)={low, medium, high} named 'Lhm'.

The system may change due to the action of processes. We can identify the following processes:

- photosynthesis (plants)
- respiration (decomposers)
- grazing, natality and mortality (fish)

Each of these processes has a rate that has to be represented as a quantity:

- photosynthesis rate
- respiration rate
- grazing rate
- natality rate
- mortality rate

We assume that the rates have QS={zero, plus} named 'Zp'.

Guidance for implementing the model in HOMER

Before starting to implement the new model, open the Windows Explorer (or similar) and create a folder named 'Second Assignment' under the GARP models folder (C:/Program Files/Garp/models) in order to save your qualitative model there.

After performing a model-building step in HOMER it is recommended that you always save your file. For saving, go to the main screen of HOMER and press 'Save'. If needed select the desired folder location (see above) and specify the filename.

1a Create an Isa Hierarchy
Represent the subtype relations between the following entities: biological entity, autotrophic entity, heterotrophic entity, fish, plant, decomposer, container, and river.

1b Create one Configuration relation
Create a configuration definition for contains to express: 'river *contains* fish'.

2 Create Quantities with Quantity Spaces
Having defined the entities (plant, fish etc), we have to define the quantities they have. Include in your model the required quantities and their quantity spaces.

3 Create a static Model Fragment (MF) for the river specifying the quantities
Now we want to represent the river and the quantities that characterize it. Build a MF that shows that there exists a river (is an entity) and it has nutrients, oxygen, carbon dioxide, and detritus (all are quantities).

4 Create 3 static MF as subtypes of the river MF from step 3
We would like to have in our model qualitative descriptions of the possible states of the river. We assume that the river can be classified as ‘eutrophic’, ‘mesotrophic’ and ‘oligotrophic’ according to the amount of nutrients.

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5 Create a Scenario
Create a scenario that specifies a river ‘containing’ plant, fish and decomposers. Each of these entities has a ‘medium’ amount of mass.

- **Export the model to VISIGARP and RUN the simulation**
  What happens to the system modeled so far? To inspect that, export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How many states are generated? Is this correct?

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6 Define the Photosynthesis Process
We want to model a plant that increases its mass due to photosynthesis at a certain rate. During the process, along with the biomass production, oxygen is also produced and carbon dioxide is removed from the river (use influences to model all these effects of photosynthesis rate). This rate is influenced by the amount of plants. Therefore: the bigger the amount of plants, the higher is the rate (use a proportionality to model this relation).

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How many states are generated? Is this correct?

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7 *Assume* constant mass for decomposers
Let’s assume that the amount of decomposers will always be stable, with the value ‘medium’. How to include this assumption in the model? Hint: first create an assumption label (in HOMER’s main menu select: ‘Assumptions…’). Next, create a static MF that describes what is being assumed. Don’t forget to include the assumption (the label) both in this MF and in the initial scenario!

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How many states are generated? Is this correct? Can you observe the effect of the assumption on the simulation?

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8 Create a static MF specifying detritus production
We want to represent that any biological entity produces detritus, which will be added to the ‘detritus’ that already exists in the river. To make things simpler, represent the relation between them as follows: when the mass of any biological entity increases, then the amount of detritus also increases.

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How many states are generated? Is this correct? What is the effect of the newly added MF?

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9 Define the Respiration Process
We want to represent the effects of the decomposers on the detritus. The mass of detritus changes due to process respiration. As a result of the process, more nutrients and carbon dioxide are being added to those already in the river, while the amount of detritus and of oxygen are being reduced (use influences to represent these effects of the respiration rate). Respiration rate is also proportional to the mass of decomposers: when the mass is increasing, the rate is also increasing (use a proportionality).

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. What is the effect of the newly added Process?

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10 Create a MF implementing a Simplifying Assumption on Respiration
We can be more restrictive when describing the respiration process. Let's assume that nutrients, detritus and carbon dioxide all change in the same direction. That is, the three amounts are increasing, decreasing or stable at the same time. This will avoid behaviors such as nutrient is decreasing while carbon dioxide is increasing, etc. Hint: create a label for the assumption, create a process MF, subtype of respiration, and use inequalities to relate the derivatives of the quantities. Add the assumption label to the MF and to the scenario.

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How many states are generated? How does the assumption affect of the simulation?

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11 Create a MF that captures the Grazing Process
We want to represent that fish eats the plants. Being a process, this grazing has a rate, which removes biomass of plant and adds to the fish biomass. This rate is influenced by the mass of fish, so that when the mass is increasing, so does the rate. We can be more specific and simplify the simulation. Include in the representation of the grazing process the following knowledge: the value 'medium' of plant biomass is equal to the value 'medium' of fish biomass. Also state that biomass of plant is equal or greater than the mass of fish. (Hint: In order to represent equality between values in QS of different quantities or to represent the relation between the two quantities, use inequalities.)

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How does the new process affect the simulation?

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12 Create a MF implementing a Simplifying Assumption on Photosynthesis
We can add more knowledge to the model in order to reduce the ambiguity involving the quantities. Include the following: nutrient and plant biomass change in the same way, that is, both are always increasing, decreasing (or stable) at the same time. Include also the idea that there exists a correspondence between the whole set of possible values that these two quantities have (e.g. interval low of nutrient correspond to interval low of plant biomass). Hint: create a label for the assumption, create a process MF, subtype of photosynthesis, to implement the assumption. Add the assumption label to the MF and to the scenario.

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How does the assumption affect the simulation?

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13 Create the basic Processes Natality and Mortality
Fish population changes due to natality and mortality processes. Start with the natality process. Represent the idea of that the process happens for fish in the river: 'the river contains fish'. Natality has a rate that represents more mass being added to the population (use an influence). This rate is influenced by the population size itself: when the population is increasing, the rate is also increasing (use a proportionality).

Mortality of fish is influenced by the amount of dissolved oxygen in the water of the river. This influence can be described as follows: being a process, mortality has a rate, which removes mass from the fish (use an influence). This rate is also influenced by the mass of fish itself: when the population is increasing, the rate is also increasing (use a proportionality). Mortality rate is also influenced by the amount of oxygen, so that when the amount of oxygen is increasing, the mortality rate decreases; and when the amount of oxygen is decreasing, the mortality rate increases (use a proportionality).

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How do the new processes affect the simulation?

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14 Simplify the Natality and Mortality Processes
The simulation produces now many states. We can add more knowledge to the model in order to reduce ambiguity. Create an assumption that can be used to simplify the natality and the mortality processes. For the natality process, assume that the mass of the fish and the birth rate change the same way (both can be simultaneously increasing, decreasing or stable). The same assumption can be applied to the death rate and the fish biomass (both can be simultaneously increasing, decreasing or stable). Thus, create two MF implementing these assumptions. One MF is subtype of

natality and the other is subtype of mortality. Add the assumption label to both MF's and to the scenario.

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How do the simplifying assumptions affect the simulation?

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15 Create an Oxygen Requirement for the Fish
The number of states in the simulation has now decreased, but the desired behavior is not very apparent yet (that is, when oxygen goes low, increase in the death rate brings the fish population to a low size). Add an assumption concerning the requirement of the fish population concerning dissolved oxygen in the water. Namely, the mass of oxygen has to be greater than or equal the mass of fish. Also, an equality between the values 'medium' of the two quantities has to be created. This knowledge can be captured in a static model fragment.

- **Export the model to VISIGARP and RUN the simulation**
  Export the model to VISIGARP, start VISIGARP, open the scenario and run a full simulation. How does this 'oxygen requirement' affect the simulation?

To further study qualitative modelling please run and analyse the models already provided in the 'models' folder of GARP. For more information about GARP, including latest developments, see http://www.swi.psy.uva.nl/projects/GARP/