Modularization of ecological models

Joachim Benz*

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*Faculty 11, Kassel University, Germany

1. Basic ideas of modularization

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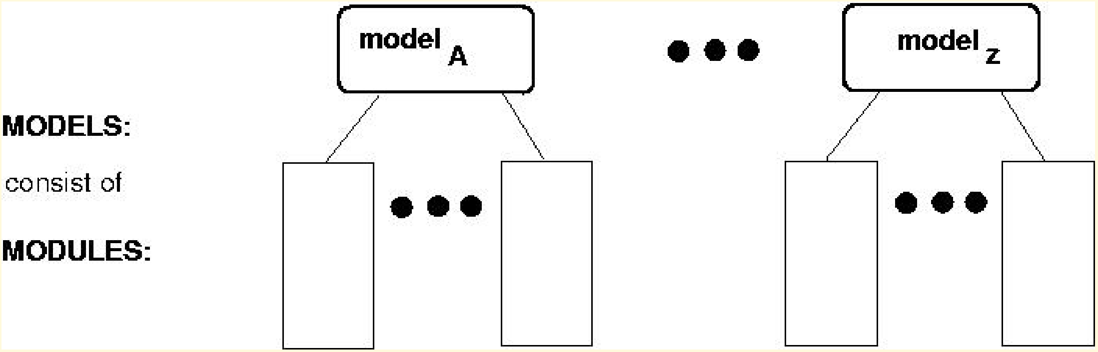
- minimization of redundancy
  (minimize the risk of inconsistencies)

Many models, in particular more complex models can be splitted into two or more sub models or modules.



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1.2. Basic types of modules

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- The third type is used to *provide data*, which are necessary to run simulations of a model. Data can be either times series or time-invariant values of certain parameter of the model. This type of document/module is called **DATA_SPECIFICATION**.

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1.3. How we can do modularization?

There are two levels of modularization. First we have to decide which variables and equations we put together in one SPECIFICATION-module. The second level of modularization is the decision which modules we put together in one AGGREGATE

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- Another aspect is based on mathematics and systems theory. If the number of modules is given, we can postulate
  1. $\frac{\sum interactions\ inside\ modules}{\sum interactions\ between\ modules} \rightarrow max.$
  2. cycles should be inside of modules

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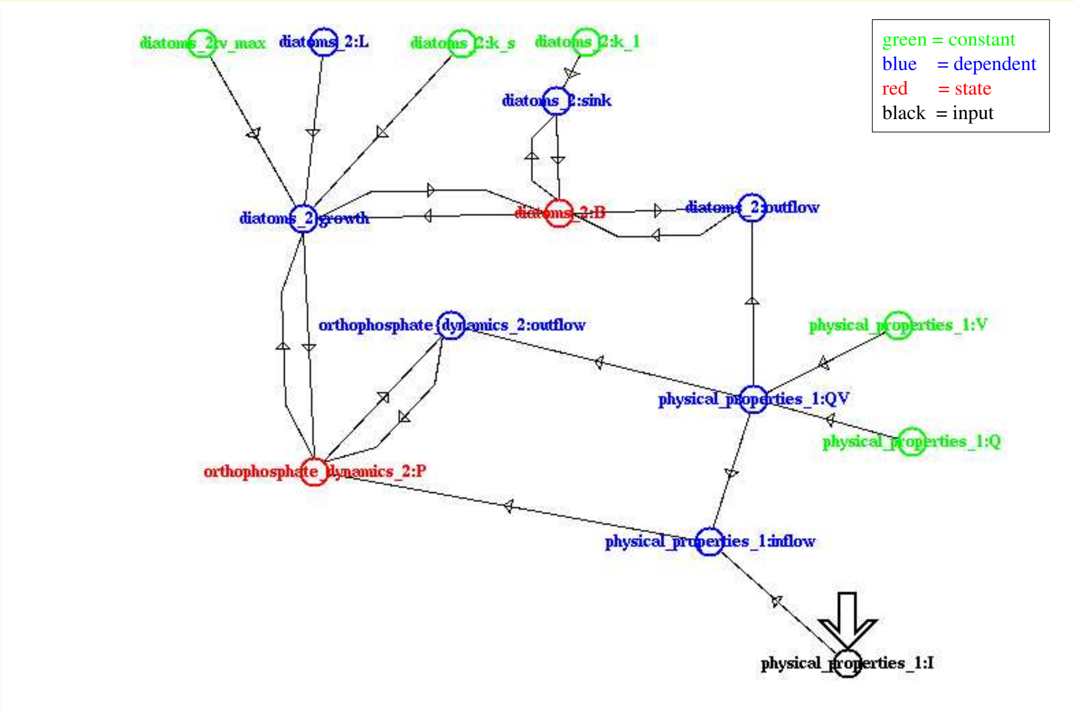
  1. $\frac{\sum interactions\ inside\ modules}{\sum interactions\ between\ modules} \to max.$
  2. cycles should be inside of modules
- List of inputs and outputs of different modules, which describe the same process should be equal . This aspect is to consider to improve the possibility to exchange these modules easily.

1.4. An example

A simple *phosphate-algae-lake* model is used to show modularization.[1]



[1]Legovic; T. and Dubravko; J. (1984): A model of diatom dynamics in the epilimnion of Lake Jezero on the island of Krk. Periodicum Biologorum, 86/3, 269-276.

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Block clustering based on the *interaction matrix*[2] is used to identify sub-structures of this model.

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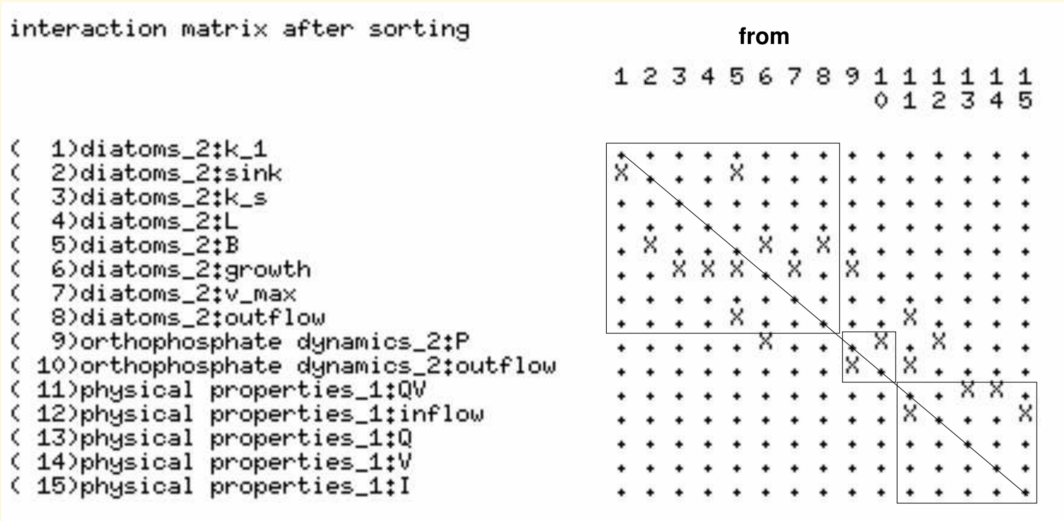

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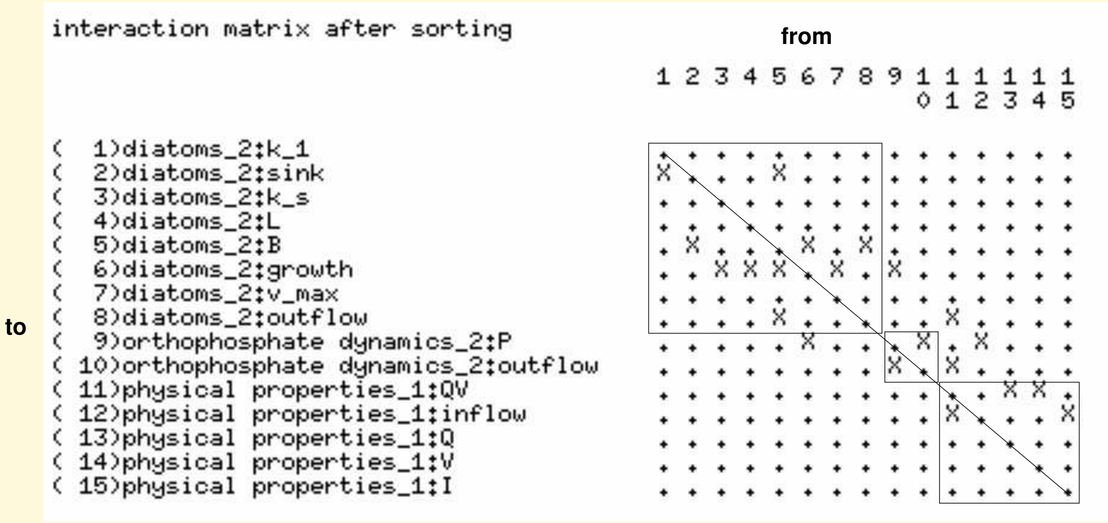

This function can be execute in EMA with:

Main menu: Check/Analyze –> Interaction Analysis

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[2]Gourlay; A.R. (1976): An algorithm for reducing the moment of inertia of a system interaction matrix. Appl. Math. Modelling 1, 131-135.

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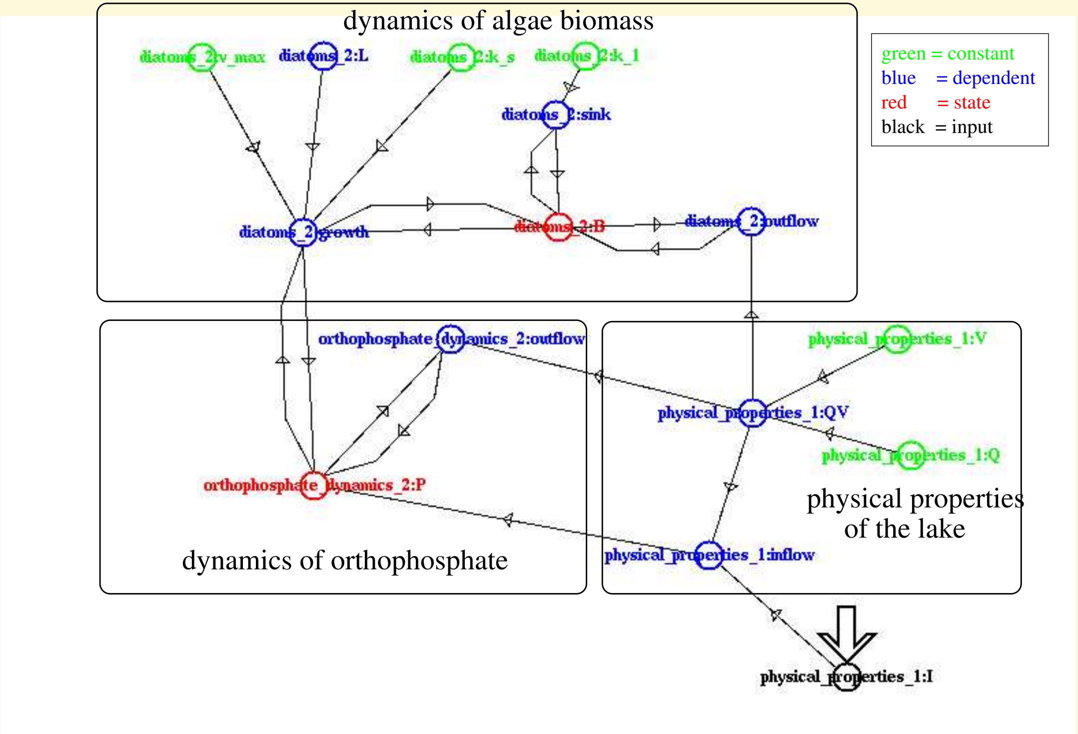
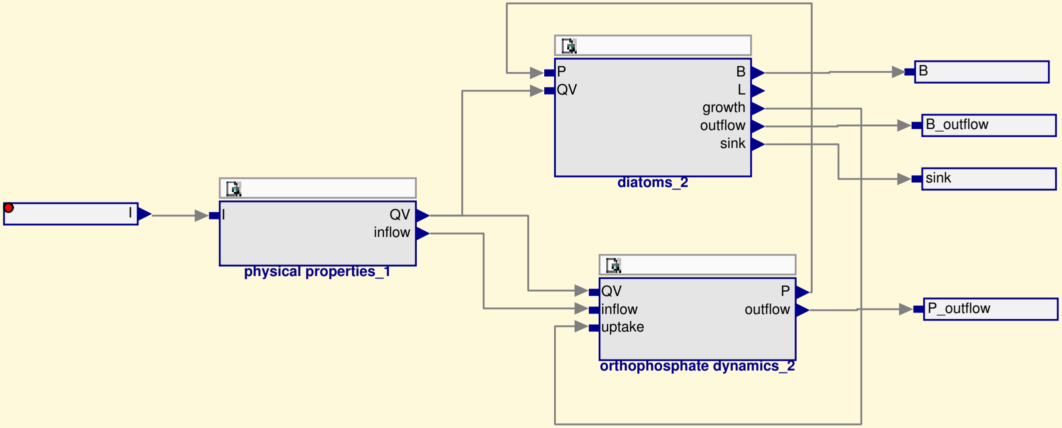
The result of the numerical method is also according our scientific understanding of this system.



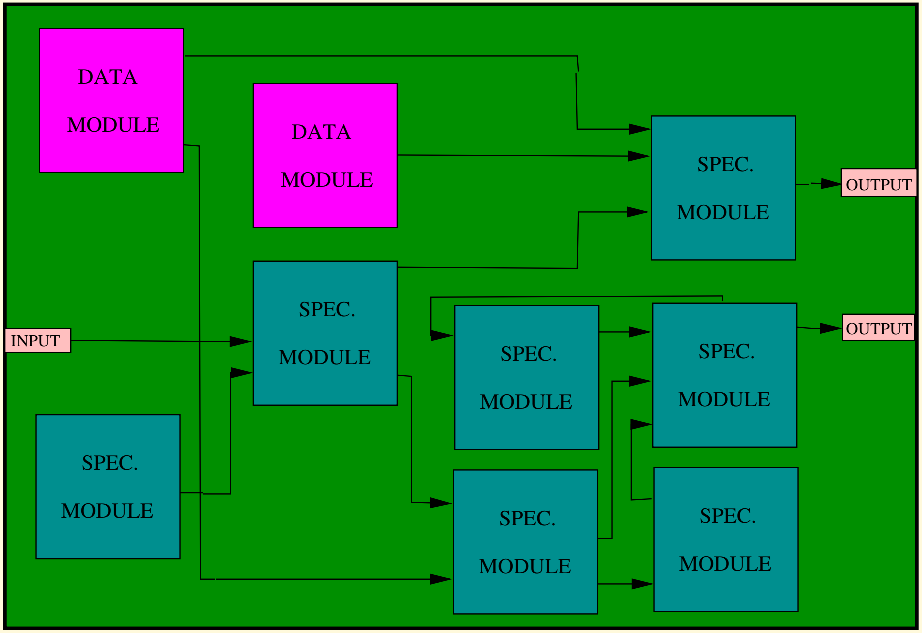
The structure of the three resulting modules is described with an **AGGREGATE** now.



1.5. AGGREGATES and hierarchy

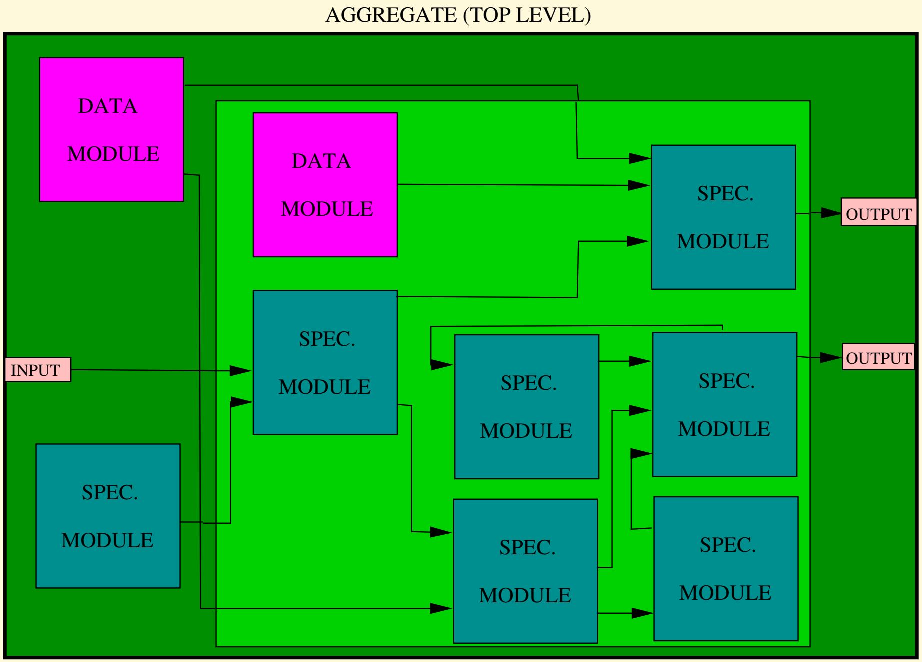
AGGREGATES with a large number of modules and connections between these modules become complex and hard to handle.

AGGREGATE (TOP LEVEL)

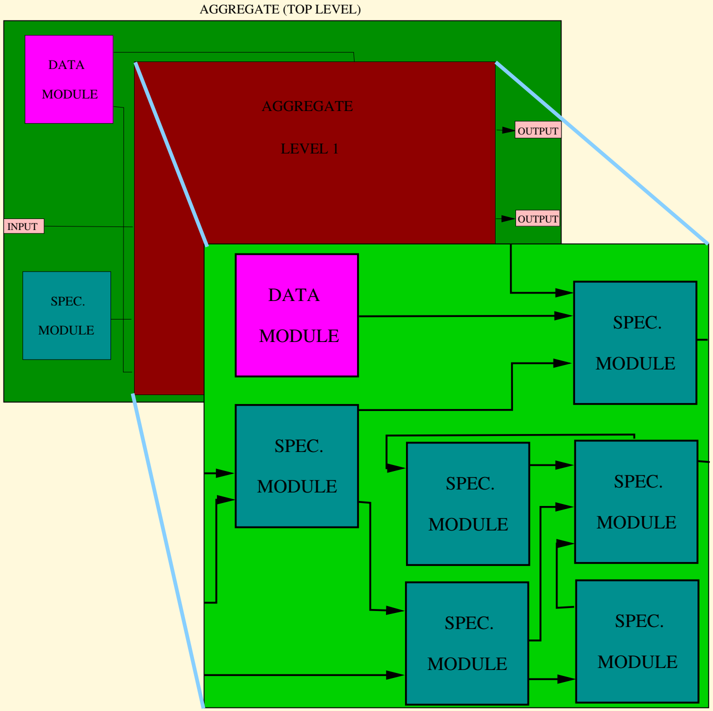


In many cases we can recognize *substructures*, that means groups of modules which belong together.

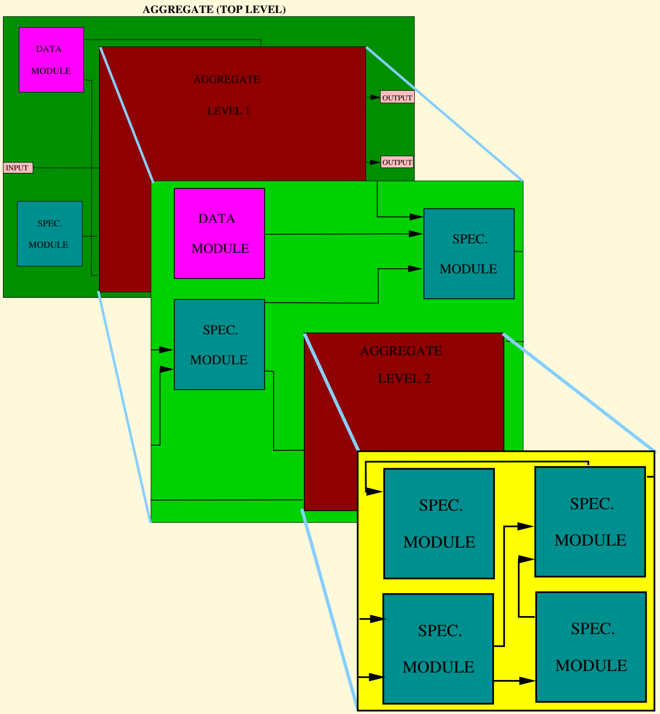
(which criteria can be used to determine which modules belong together see the section above)



For such subgroups of modules, we can formulate separate AGGREGATES, which are embedded in the top-level AGGREGATE.



Because AGGREGATES can consist of both SPECIFICATION and AGGREGATES, hierarchy can be described in ECOBAS easily. By this procedure we get smaller AGGREGATES which can be handled easier. And in addition we introduce the possibility to exchange parts of the model at different levels of the model structure.



2. Redundancy reduction

To minimize the risk of inconsistencies it is useful to reduce redundancy.

Here we can apply similar principles as they are used to optimize the design of (relational) databases.

2.1. SPECIFICATION and MATH-Module

In ecological applications **SPECIFICATION** modules consist not only of

- declaration of variables and equations

but also

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In ecological applications **SPECIFICATION** modules consist not only of

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- units,
- ranges of validity and
- the meaning of the used variables as well.

Ecological models contain more than mathematical models. In addition to the mathematics and the values, we need

- ecological context information and
- information about used measuring methods

to satisfy the scientific requirements of

- reproducibility,
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In a further step we separate now the '*pure*' mathematical information

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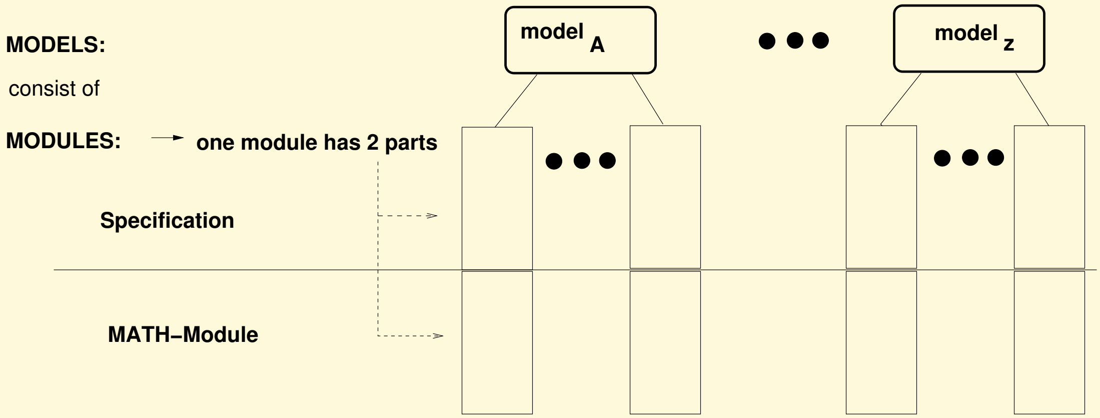
Specification module still holds the definition of values and information about units, ranges of validity and the meaning of the used variables as well. In addition linkages to ecological context information, measuring methods of certain values, literature and persons are given in this module.

Now we can say: A model consists of one or more modules which are always a pair of one Specification and one Math-Module (except AG-GREGATES and DATA modules).



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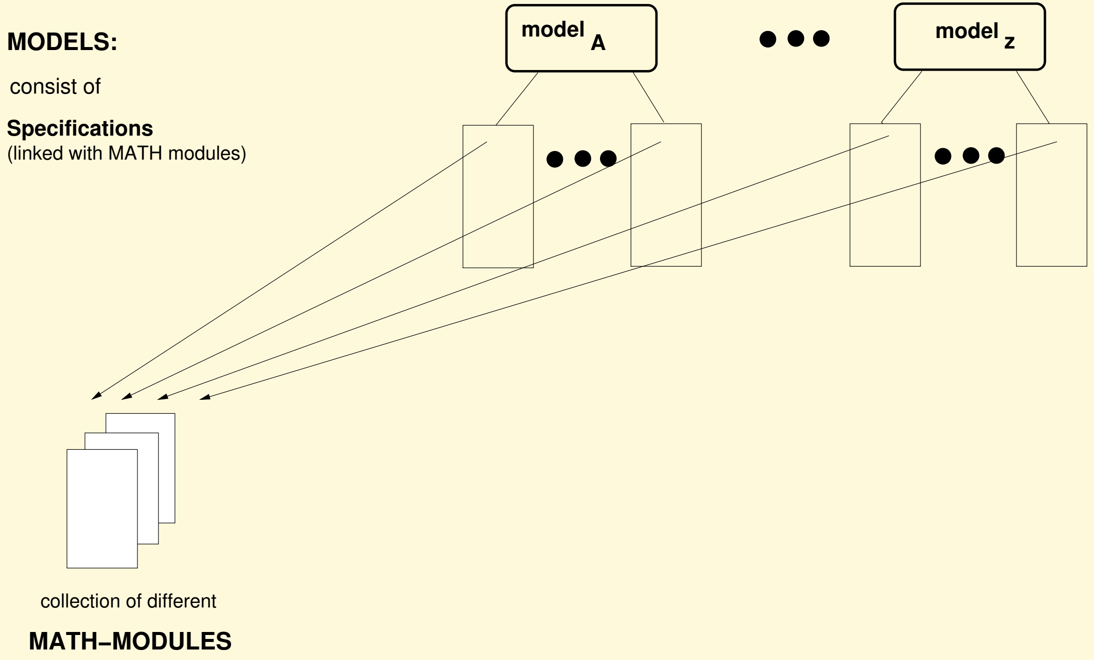
If this assumption holds, it is possible to reduce redundancy by separation of SPECIFICATION and MATH- modules. Because we need only one MATH module and link this with the two SPECIFICATION modules.

By this separation the modeler has the possibility to formulate only one set of mathematical formulations (= MATH module) which can be used in different models.



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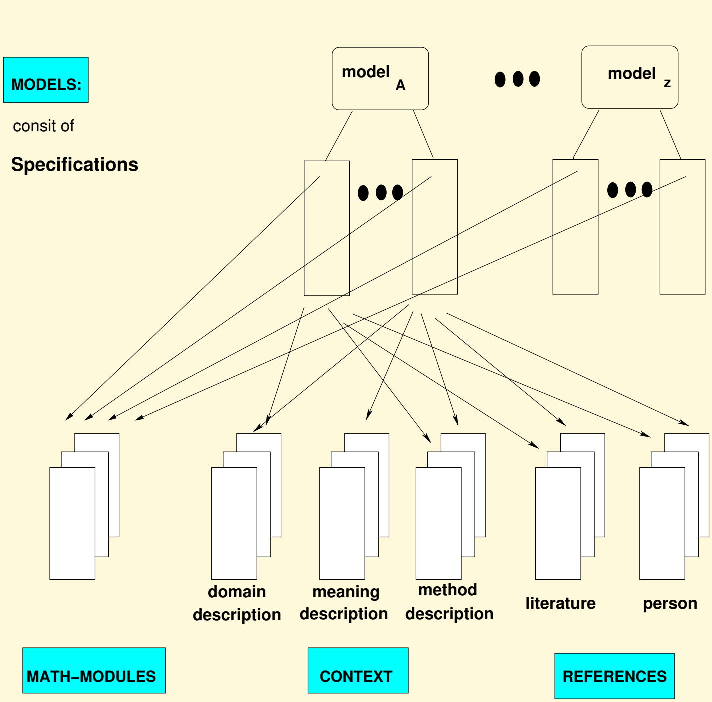
2.2. Ecological context and other additional information

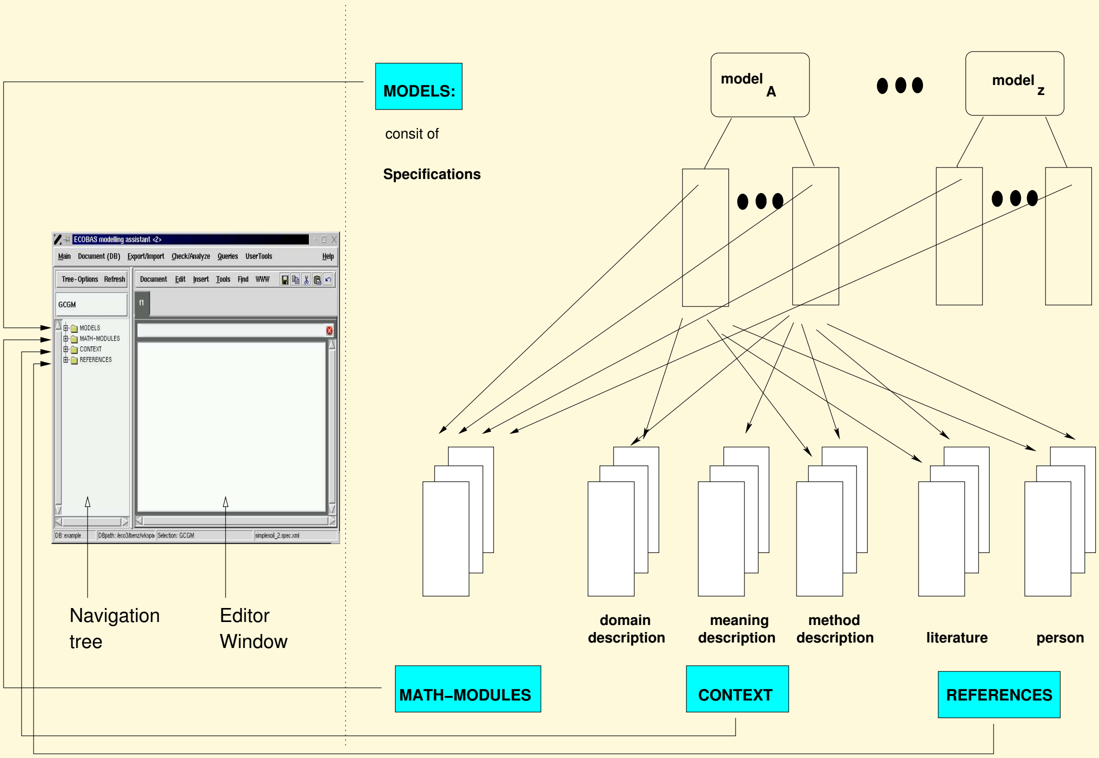
In the same way as we did it with **MATH modules**, we can proceed with ecological context and other additional information.



3. How it is implemented in ECOBAS

group	document name	content
MODELS		
	MODEL_ID	short description of a model
	SPECIFICATION	values, units and links to: • corresponding MATH-MODULE • domain description • meaning of variables • measuring methods • literature reference • information about persons
	AGGREGATE	how are two or more modules connected
	DATA MODULE	supply data of a model
MATH-MODULES		
	MATH-MODULES	description of the mathematics • declaration of variables • equations
CONTEXT		
	DOMAIN	description and classification of the ecological environment
	MEANING	meaning of variables
	METHOD	information about measuring methods
REFERENCES		
	PERSON	information about a person
	LITERATURE	literature reference

All these types of documents can be found and accessed in EMA's navigation window.



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