Overview

- Learning and simulations
- Research questions
  - Diagnosing learning behaviour
  - Curriculum planning
  - Explanation (incl. visualisation) *(brief)*
- Concluding remarks
- Applications and References *(brief)*

Explanation!

How to generate explanatory discourse?

- ‘Canned text’ and templates are inflexible
- ‘Translating the code’ is unnatural

So, how to generate explanatory discourse **automatically**?

- <u>generic</u>, possible to re-use
- <u>flexible</u>, based on student’s needs

Explanation!

Separating the **WHAT** *(content)* from the **HOW** *(form)*

WHAT: curriculum planning and didactic goals

- Different levels of time:
  Over sessions, during one session, one discourse event

- Different levels of content:
  Curricula, Topics, Issues, Concepts, Rules, Facts

HOW: graphics, text, VR, animations, etc.

Overview

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Curriculum Planning & Didactic Goals

The Problem

…dividing the subject matter into pieces (parts)
that can be dealt with by learners ...

Issues

- What parts should be singled out?
  (According to what criteria ?)
- Where to start ?
  (Simple to complex, Conditional, etc.?)
- How to proceed?
  (According to what criteria?)

Example: Arithmetic

- What is more difficult? And Why?

$$\begin{array}{rl} 5 & \\ \underline{4} & + \end{array} \qquad\qquad \begin{array}{rl} 5 & \\ \underline{4} & - \end{array} \qquad\qquad \begin{array}{rl} 5 & \\ \underline{4} & x \end{array}$$

$$\begin{array}{rl} 5\ 5 & \\ \underline{4} & + \end{array} \qquad\qquad \begin{array}{rl} 5\ 5 & \\ \underline{4} & - \end{array} \qquad\qquad \begin{array}{rl} 5\ 5 & \\ \underline{4} & x \end{array}$$

$$\begin{array}{rl} 5\ 5 & \\ \underline{4\ 4} & + \end{array} \qquad\qquad \begin{array}{rl} 5\ 5 & \\ \underline{4\ 4} & - \end{array} \qquad\qquad \begin{array}{rl} 5\ 5 & \\ \underline{4\ 4} & x \end{array}$$

E.g.
- *number of inference steps (borrow is more difficult)*
- *memory load*
- *the number as such (9 more difficult than 2)*

Didactic Principles: ***examples from literature***

- from simple to complex / from easy to difficult
- from known to unknown
- from general to specific (<u>OR:</u> from specific to general)
- alternative viewpoints
- opportunistic
- structure versus behaviour
- on the basis of dependencies (conditional foreknowledge)

Research question:

What are the dimensions that define the space of ‘subject matter sequencing’?

Ideas on model dimensions *(a selection)*

- Genetic Graph
  (Goldstein, 1979)

- Causal Model Progression
  (White & Frederiksen, 1990)

- Compositional Modeling
  (Falkenhainer & Forbus,1991)

- Models for Ecology
  (Salles & Bredeweg, 1997 & in press)

Genetic Graph *(Goldstein, 1979)*

Domain knowledge:

Logical & probabilistic reasoning

(represented as a set of rules)

Definition:

A knowledge representation consisting of individual pieces of knowledge which are connected by learner-oriented links representing the evolutionary nature of knowledge.

Dimensions:

- Refinement
- Analogy
- Generalisation / Specialisation

Causal Model Progression *(White & Frederiksen, 1990)*

Domain knowledge:

Diagnosing electronic circuits

Definition:

... To start with a simplified (simple) world (model) and to have a coach progressively add new dimensions of complexity that require an increasing mastery of expertise (skills)…

Dimensions:

- Perspective
- Order
- Elaboration

Causal Model Progression *(Dimensions & Learning)*

Dimensions

- **Type (perspective)**

  e.g.: V = I x R versus electrons

- **Order**

  zero order (on/off)

  first order (changes)

  second order (‘relative’ changes...)

- **Elaboration**

  more intermediate dependencies

On learning

- Within the current model *(e.g.: solve a diagnostic problem)*
- With respect to next model (level)

  - unsolvable problems *(need for more complex model)*

  - explanation on differences between models

Causal Model Progression *(Statements on Learning)*

‘... as a student learns her model becomes **elaborated** - changes in degree - by including further constraints. More radical transitions take place when a new **order** or a new **type** is introduced…’

‘...deep understanding does not consist of a single model, but is characterized by the coexistence of a set of complementary models that vary along the dimensions…’

Related work: Sime *(ITS’96 / AIED’95)*

Using multiple models/ perspectives

(Cognitive Flexibility approach)

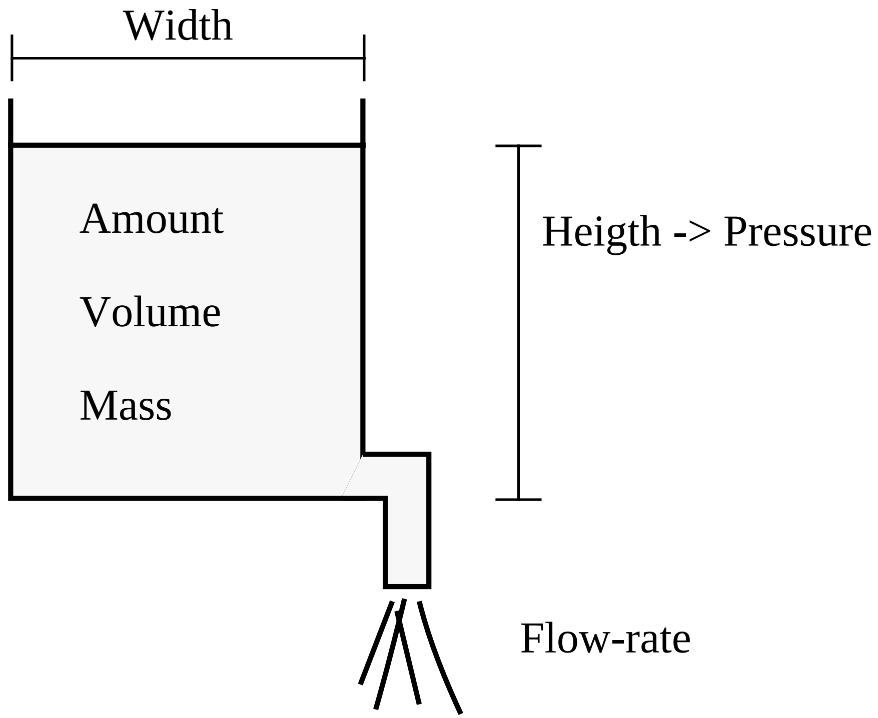
Compositional Modeling *(Falkenhainer & Forbus,'91)*

A more technical concern: getting the simulation right !

Example: ***Which quantities to use ?***

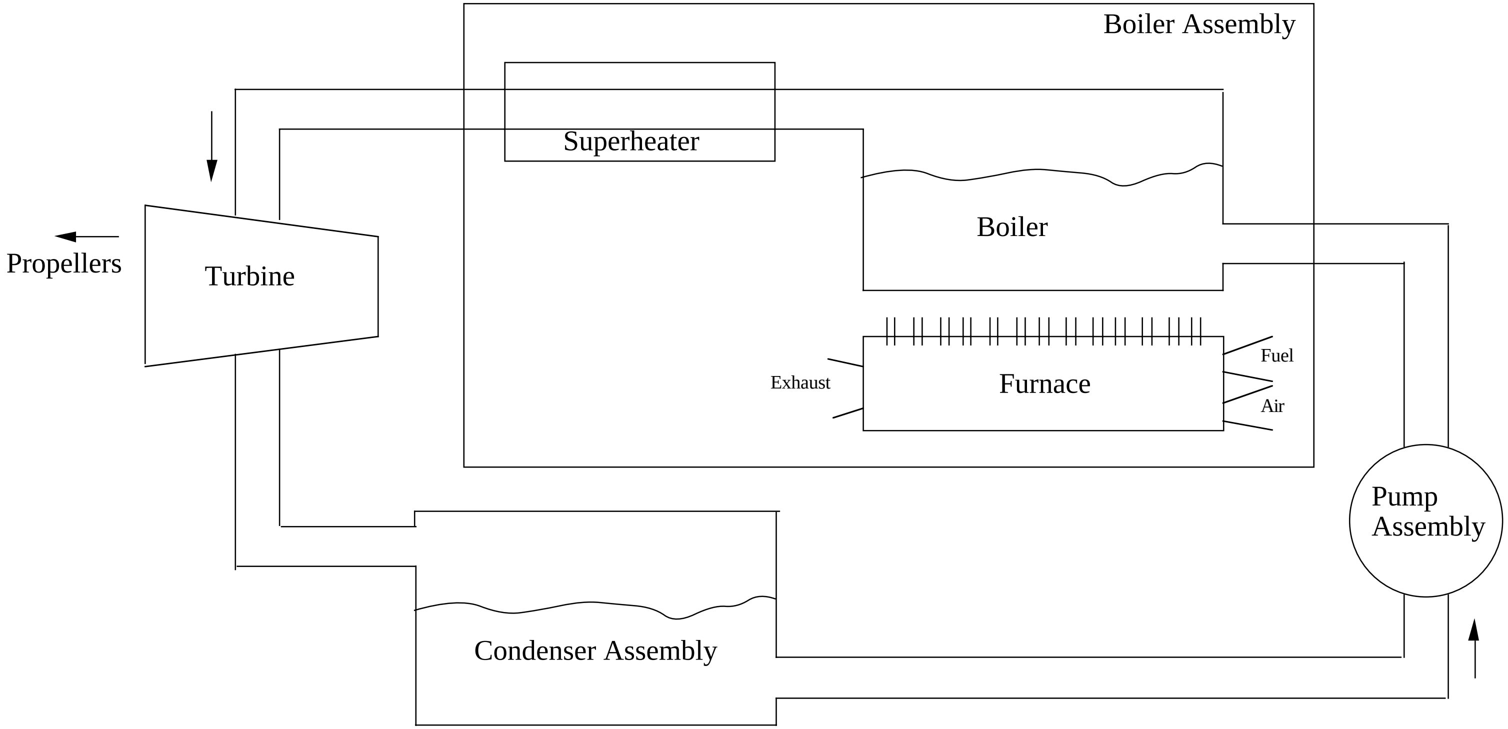
- temperature
- heat capacity
- materials (container, liquid)
- thickness
- boil point, freezing point
- turbulence
- with of outlet
- forces between molecules

- … (many more)



Compositional Modeling *(Domain example)*

Steam-powered propulsion plant



(cf. Falkenhainer & Forbus, 1991)

Query: *How does an increase in the furnace fuel/air ratio affect the amount of steam flowing in the superheater?*

Compositional Modeling *(Model dimensions)*

Simplifying assumptions

- Perspective / Ontology *(The view taken on the physical system)*
- Granularity / Grain-size *(How much structural detail to include?)*
- Approximation / Abstraction *(What behaviours to take into account?)*

Operating assumptions

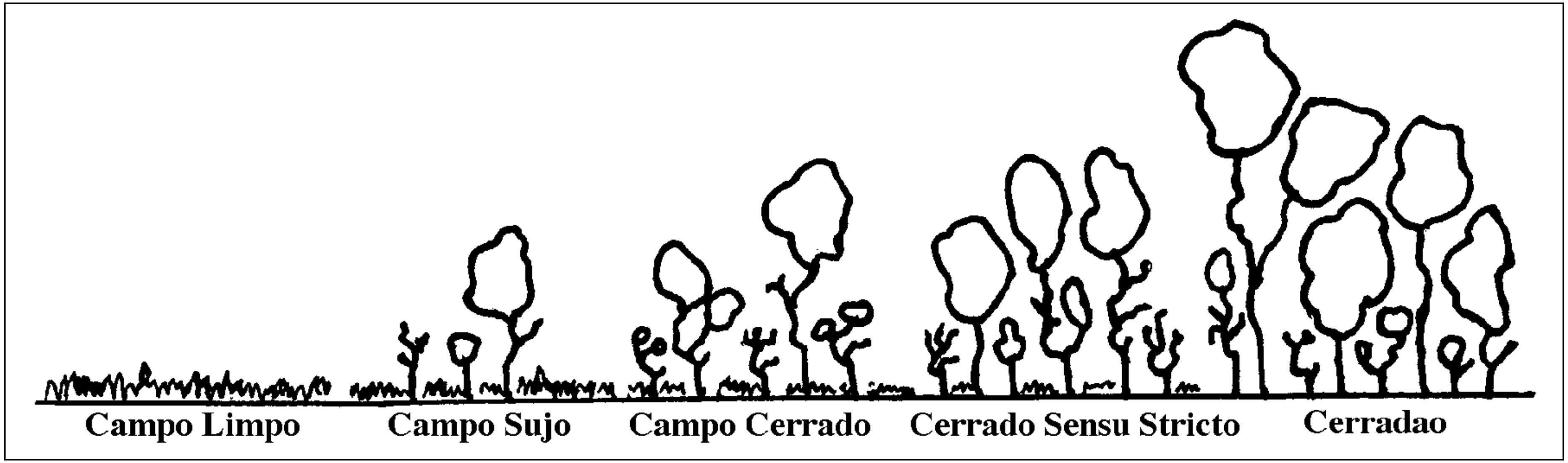
- *Boundaries / constants / starting values*

(compares to "Experimental frame")

In order to do:
- Query analysis
- Object expansion
- Candidate completion
- Candidate evaluation and selection

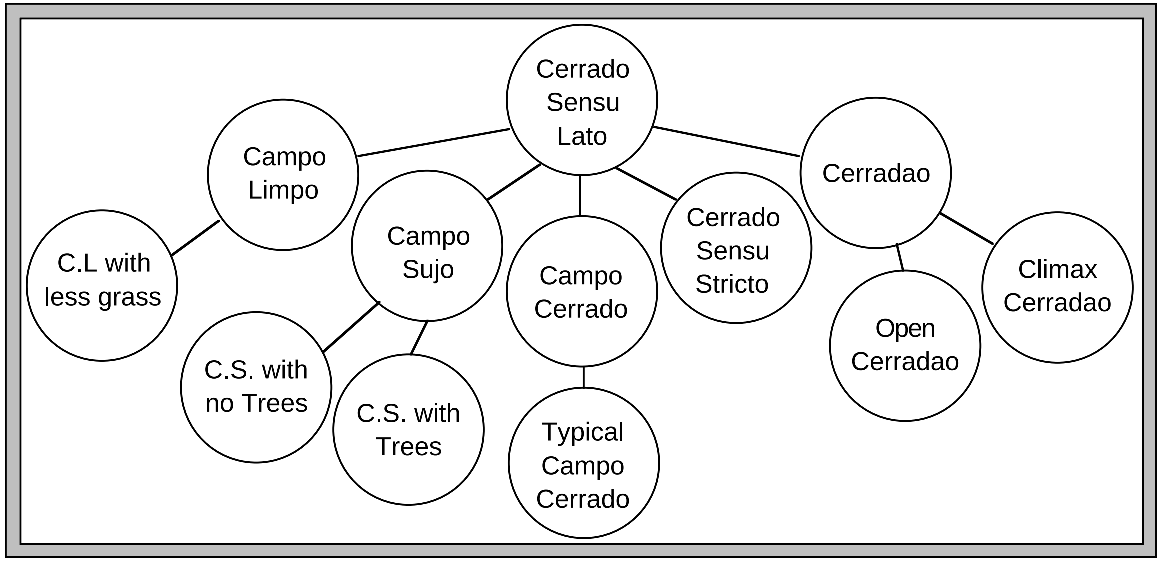
Models for Ecology *(Salles & Bredeweg, 1997 & in press)*

Fire management in the Brazilian Cerrado

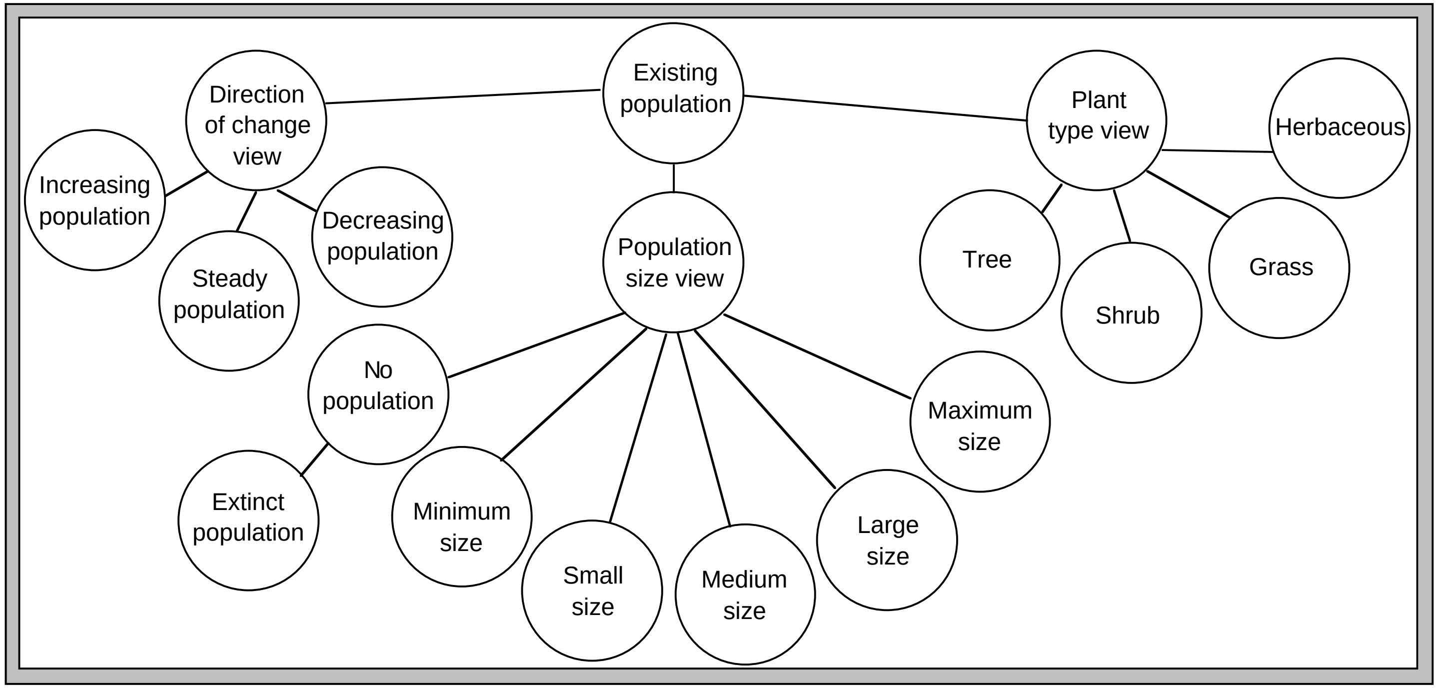


Models for Ecology *(Model fragments 1: views)*

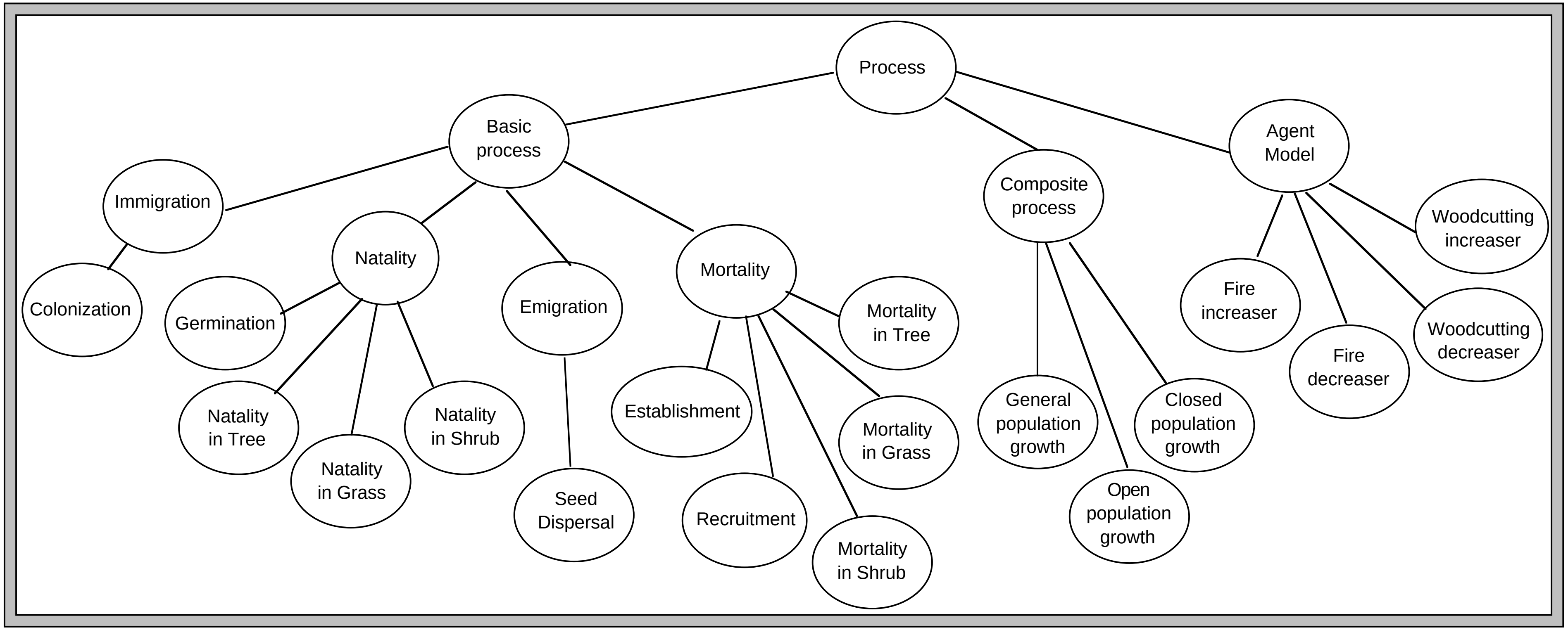
about multiple entities...



about single entities...

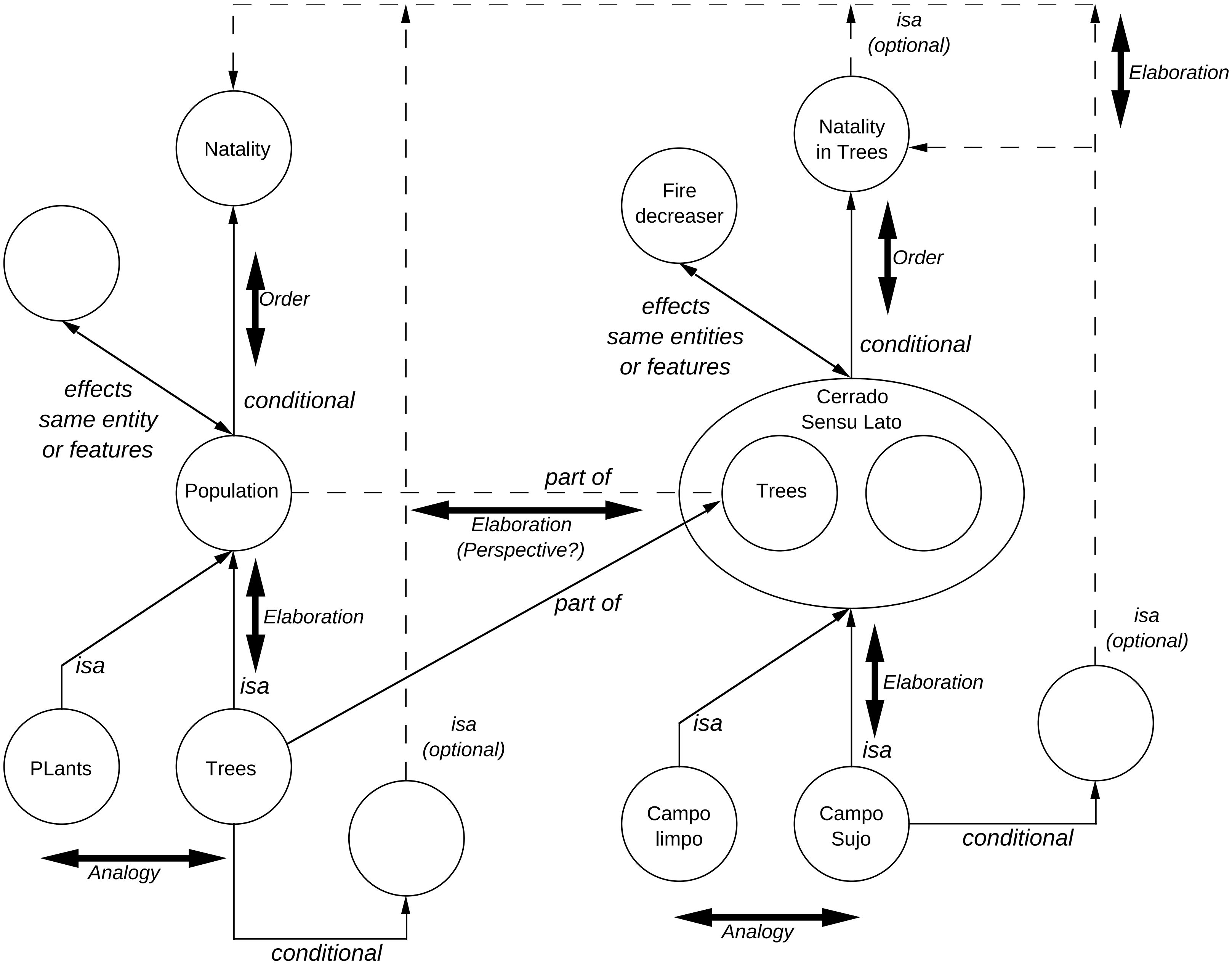


Models for Ecology *(Model fragments 2: processes)*

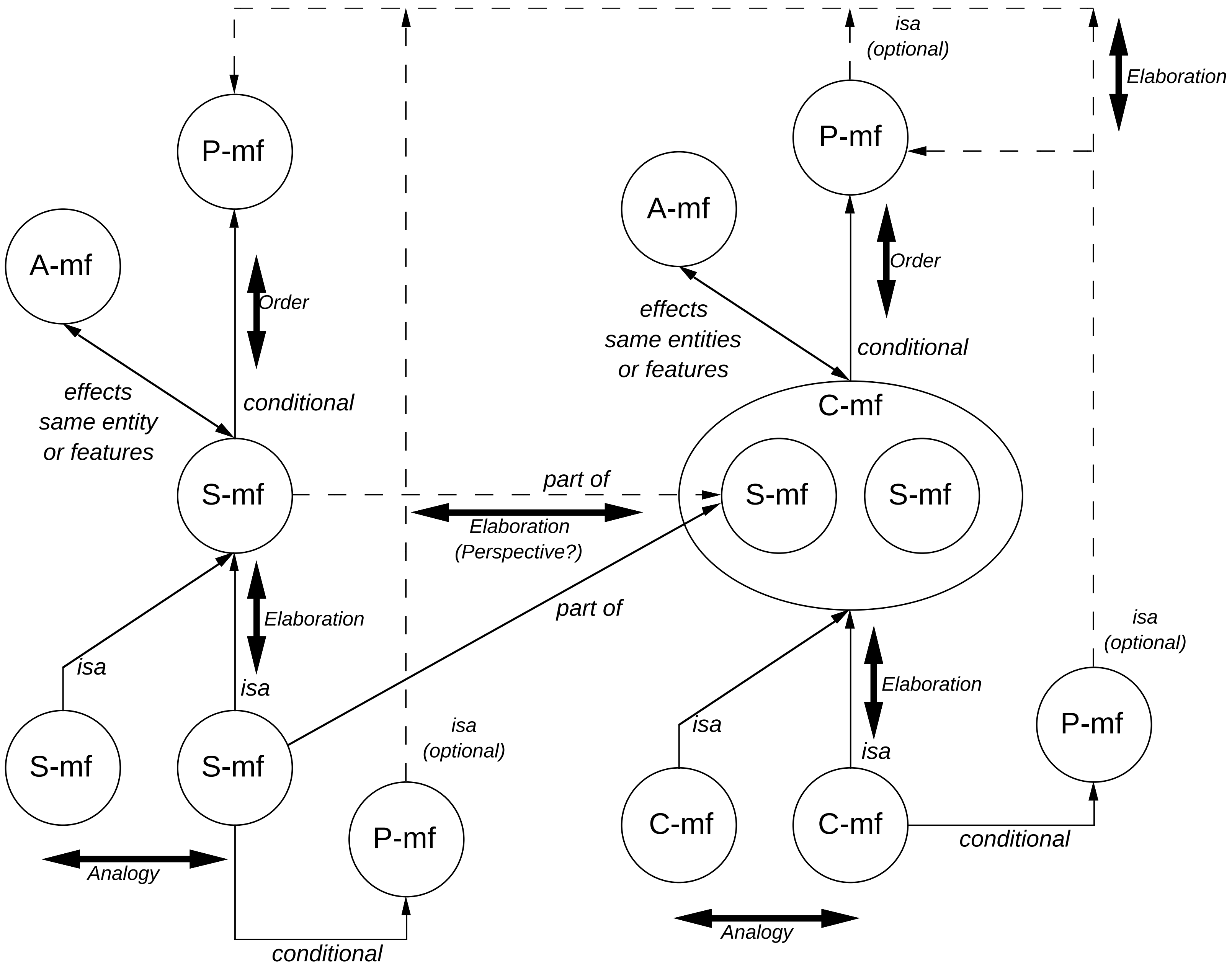


processes concerning single and multiple entities...

Models for Ecology *(Ordering by Model Fragment type - 1)*



Models for Ecology *(Ordering by Model Fragment type - 2)*

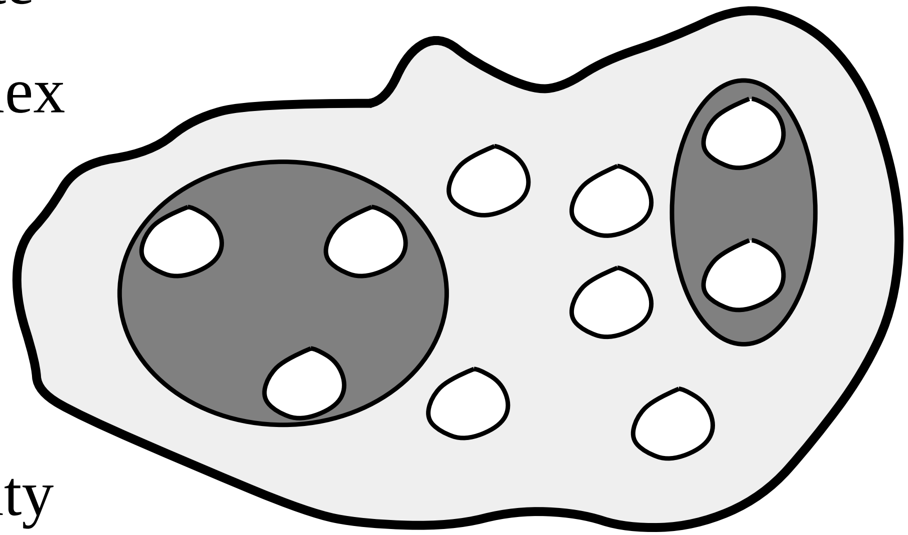


Curriculum planning *(summary)*

How to carve up the subject matter into partial simulation models which are 'digestible portions' for a learner ?

Each model should be:

- Technically sufficient
- Match students knowledge state
- Progress from simple to complex



Issue:

Dimensions for model complexity

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Principles of Explanation

Based on Winkels (1992) and Moore (1996)

- **Coherence**: explanations should be structured
- **Sensitivity**: to user’s knowledge, goals, task, prior dialogue
- **Signaling**: give overview, point out relationships
- **Responsiveness**: offer feedback and further explanations
- **Flexibility**: multiple ways of achieving communicative goal

Explanation: Skeletal Strategy Structures

Implements coaching principles, together with refinement rules

A general strategy consists of six parts:

- Announcement
- Context
- New Information
- Consolidation
- Evaluation
- Closing

Explanation: HOW - Visualization

Basic idea

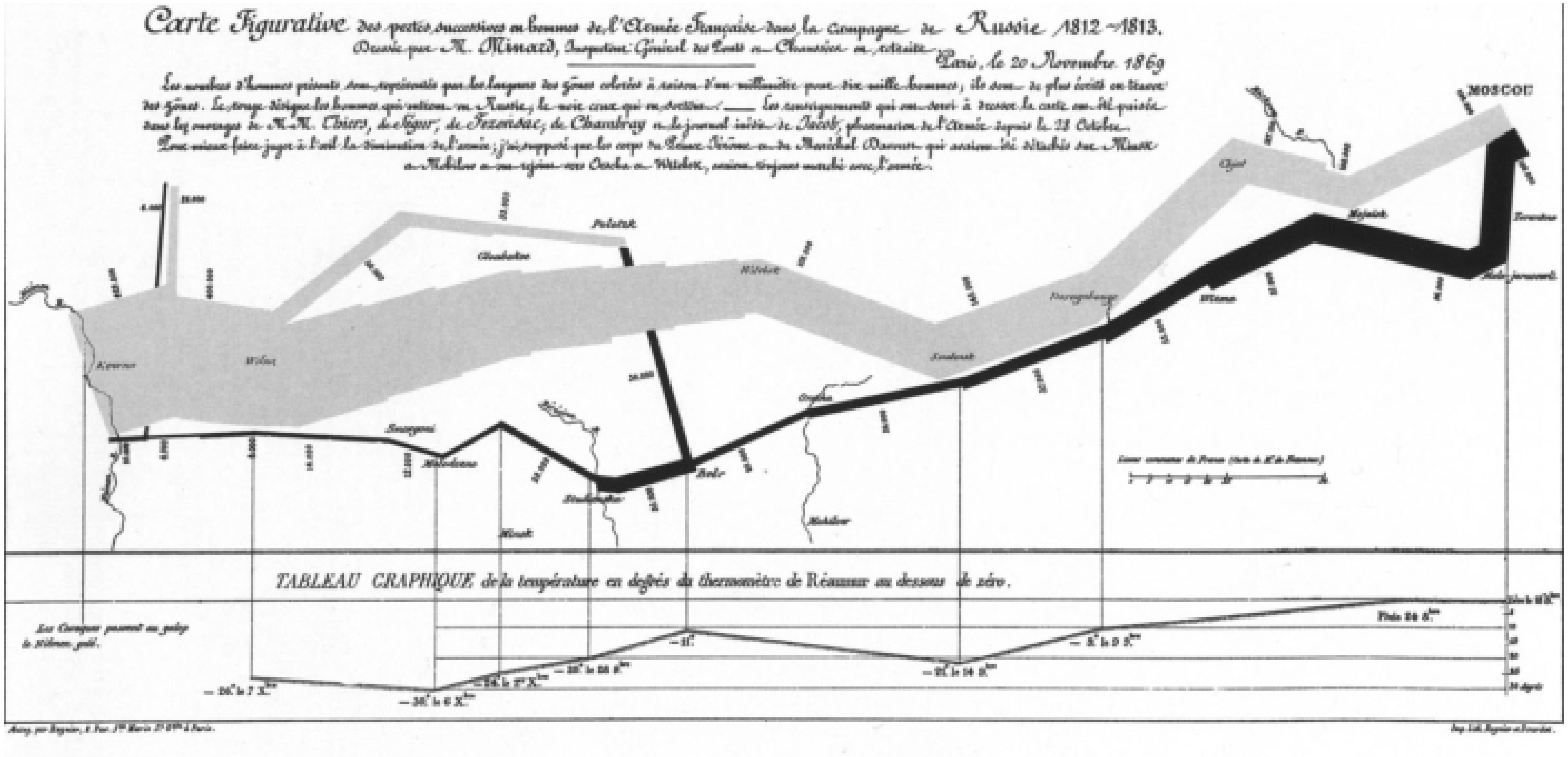
Representation: ‘Analogical’ *versus* ‘Propositional’

Advantages of analogical

- explicit representation *(more direct)*
- effective control *(reasoning process)*
- more natural/understandable *(to humans)*

Explanation: HOW - Example

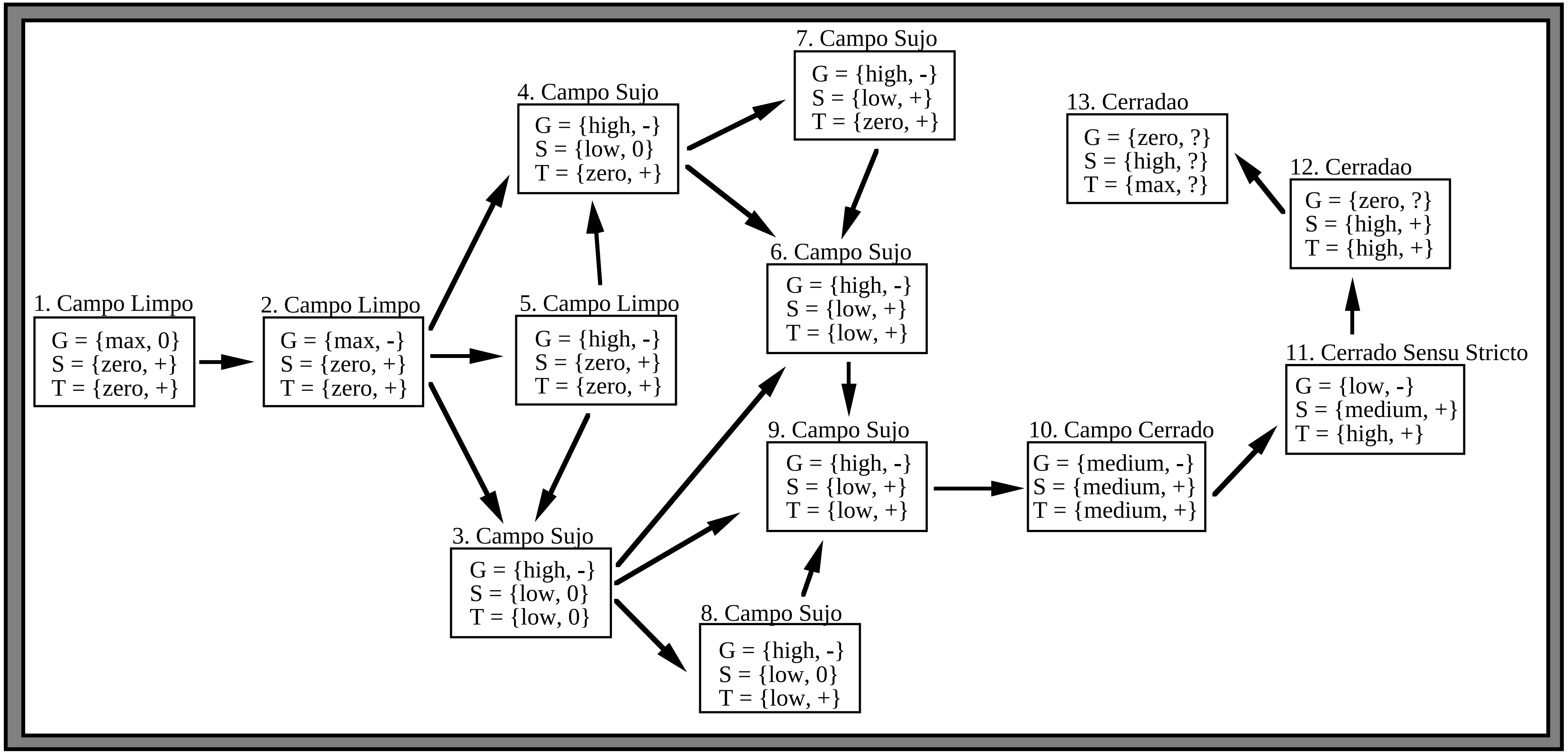
Manard's plot of Napoleon's Russian Campaign, 1813



CHAPTER 4, FIGURE 1. Charles Joseph Minard's famous plot of Napoleon's Russian Campaign. (Reprinted, with permission, from Tufte, 1983.)

Explanation: HOW - Example

Fire management in the Brazilian Cerrado



Showing only 'number_of' grass, shrub, and tree, and not the other '40 quantities'...

Explanation: HOW - Example

Visual languages

- Vocabulary of graphical symbols
- Diagrammatic rules
- Expressiveness - *all facts (and only all facts)*
- Effectiveness - *easy of expressing / perceiving*
- Emergent properties

Visualization

A very different perspective… ?

Concluding remarks

• Simulation models are getting more articulate,
but we are not there yet…

• Teaching functions are being addressed,

  • Interpretation of learner behaviour: well understood, but...

  • Curriculum planning: many ideas, no integration yet...

  • Structured explanation / visualisation: open area…

Not addressed in this talk, but interesting:

  • WWW: collaborative learning/interacting with simulations

  • Learning by <u>building</u> models

Applications and Case studies

- **Cycle pad**
  http://www.qrg.ils.nwu.edu/software/software.htm

- **Thinker tools**
  http://thinkertools.berkeley.edu:7019/index.html

- **Auto Steve**
  http://www.isi.edu/isd/VET/steve-demo.html

- **SIMQUEST**
  http://www.simquest.to.utwente.nl/simquest/

Older work…

- **ITSIE**
  (Intelligent Training Systems in Industrial Environments, finished end 1993)
  http://www.newcastle.research.ec.org/esp-syn/text/2615.html

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