Communicative interaction for acquiring conceptual systems knowledge

Bert Bredeweg
University of Amsterdam, Netherlands

QR group (part of FCN @ IvI)
Jochem Liem, Wouter Beek, Floris Linnebank, Sander Latour, Kamal Kansou & Rachel Or-Bach

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Overview

• Problem statement and Context
• Knowledge representation and Reasoning
• Progressive learning spaces
• Feedback for Reflective thought
  – Semantic Web techniques (model ingredients)
  – Consistency-based Diagnosis (simulation results)
• Inducing Motivation
• Concluding remarks
The water temperature and pressure increase.
The water starts boiling, steam is generated.
All the water has turned to steam.
The substance temperature and the temperature of the heater become equal.
The boiler explodes, because the internal substance pressure is too high.

What happens? Why?
32. Which of the following organisms is the first to be adversely affected by thermal pollution in a stream?

(A) Trees along the bank
(B) Insect larvae in the water
(C) Large fish migrating up stream
(D) Birds drinking the water
(E) Bacteria in the water
Envisioning (Mental simulation)
Context and Relevance

• Having learners acquiring *conceptual knowledge* of system’s behaviour.
  – *Important* for society to successfully interact with its environment.
  – Being able to adequately *explain* and *predict* the behaviour of systems to utilise their functioning for human benefit.
  – A *prerequisite* for working with numerical models and equations.

• Hence, policymakers and other stakeholders strive to accomplish *effective science education*.
What does it entail?

- **System selection**
  - Identify entities (and structure)
  - What is relevant/irrelevant?
  - Structure versus behaviour

- **Determining Processes (incl. start/stop)**

- **Quantities**
  - Causal relationships
  - Critical landmarks
  - Qualitative distinct behaviours

- **Assumptions / Perspectives**

- **Etc.**

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**Artificial Intelligence & Education:**
- Mettes and Roossink, 1981;
- Kleer and Brown, 1984;
- Elio and Sharf, 1990;
- Ploetzner and Spada, 1998;
- Schumacher and Gentner, 1988;
- Frederiksen and White, 2002;
- Forbus and Feltovich, 2001;
- Schwarz and White, 2005;
- etc…

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*UvA/IvI Jan 11th, 2011*
DynaLearn - Main objective

- To develop an interactive learning environment that allows learners to construct their *conceptual* system knowledge.
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Qualitative Reasoning Engine

- Scenarios
- Initial values
- Assumptions

Library of model fragments → Qualitative reasoning engine → Behavior graph

Transition rules
Example: Population dynamics

- How do populations in general behave?
- What processes determine their behaviour?

- **Issues**:
  - Size (*number of individuals*)
  - Birth / Natality
  - Death / Mortality
Qualitative Reasoning Engine

- Scenarios
- Initial values
- Assumptions
- Library of model fragments
- Qualitative reasoning engine
- Behavior graph
- Transition rules
Capturing partial knowledge

Influence:
The amount of Birth increases Number of

Proportionality:
Changes in Number of determine changes in Birth

Mathematical foundation

Red: Condition
Blue: Consequence
Causality → Directedness

- We say that:
  - An increase (or decrease) in Force causes an increase (or decrease) in Acceleration
  - An increase (or decrease) in Mass causes a decrease (or increase) in Acceleration

- But we do not say:
  - An increase in Acceleration causes …
Qualitative Reasoning Engine

- Scenarios
- Initial values
- Assumptions

Qualitative reasoning engine

Library of model fragments

Behavior graph

Transition rules
Simulation
Simulation results

State-graph & Behaviour Paths

State-graph

Behaviour path

Green frog: Number of
Large Medium Small Zero
1 6

Green frog: Birth
Plus Zero
1 6

Green frog: Death
Plus Zero
1 6

Green frog: Number of
Large Medium Small Zero
2

Green frog: Number of
Large Medium Small Zero
3 4

Green frog: Number of
Large Medium Small Zero
3 5 7
NaturNet-Redime

http://www.garp3.org

Special issue: Ecological informatics, 4(5-6), 2009
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Representation scaffolds

• Acquiring conceptual knowledge of system behaviour is difficult
  – How to support learners in discovering and constructing this knowledge?

• Idea/Approach → Learning spaces
  – Create a set of progressive workspaces for learners to work through.
  – Each space with specific knowledge representation & reasoning features relevant to system behaviour.
Requirements and Support

• Learning space: *requirements*
  – Be logically self-contained (to allow simulation).
  – Highlight unique and relevant aspects.

• Learning space: *support delivered*
  – *Focus + Consistency*: a restricted set of primitives at each level to construct knowledge.
  – *Reflection*: simulation provides learners an instrument for reflecting upon their understanding.
Progression of Learning Spaces

1. Concept map
2. Causal model - single state - dec/std/inc
3. Causal model - state graph - dec/std/inc - q-values
4. Causal differentiation - Rates & propagation
5. Conditional knowledge
6. Knowledge Re-use - Scenario & MF’s
Learning spaces

1. **Concept map**
   - Which concepts are involved and how are they related?

2. **Basic causal model**
   - What constitutes the system (structure vs. behaviour)?
   - How do changes propagate through the system?

3. **Causal model with state graph**
   - Which quantities may reach critical landmarks? What are these landmarks?

4. **Causal differentiation**
   - What is the (initial) cause of change? How are changes propagated?
   - What processes are involved? What external ‘agents’ are involved?

5. **Conditional knowledge**
   - Are their behaviours that only occur under specific conditions?

6. **Generic and reusable**
   - System independent descriptions facilitating simulation of scenarios with an ‘arbitrary’ set of system features
LS2 - Causal model (Building)

Configuration

Contains

Entity

Causal dependency

Quantity

Assigned value

Derivative (change)

Volume

Diameter

Height

Container

Liquid

Volume!

Height!

Diameter!

Reaction force*
LS2 - Causal model (Simulating)

Inferred value
What is discovered at LS2?

- Entity / Quantity distinction
  - Important improvement over concept maps!
- Causal dependencies (→ overall causal model)
  - Between which quantities?
  - Positive / negative?
- Ambiguity
- Inconsistency
- Extra: Also available as Teachable agent mode

Bredeweg et al., 2010 (EC-TEL, LNCS 6383)
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Generating feedback

Expert/teacher

DBpedia

Student

http://dbpedia.org/resource/Size

http://dbpedia.org/resource/Population

http://dbpedia.org/resource/Mortality_rate

Semantic repository

Mf03b population has number of individuals

Mf03b population has number of individuals

Population

Population

Number of

Number of

Death rate

Death rate

DynaLearn

Zsmbmax
Max
Big
Medium
Small
Zero

Zsmbmax
Max
Big
Medium
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Positive

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Generating feedback

e.g., “You can complete your model with a P+ proportionality”

E.g., “Users who modelled death also modelled birth”
Matching - by Dimension

- Generalisation / Specialisation (G/S)
- Analogy (A)
- Inverse (I)
- Order (O)
- Structural change (SC)
- Equal (=)
Matching - by Dimensions

Germination

Natality

Immigration

Colonization

Establishment

Mortality

Emigration

Seed dispersal

G/S

Inv

A

G/S
Relating models
I know of models that are:
- More specific
- More general
- Analogous
- Inverse

compared to what you have…
Feedback – “Focussed”

What about modelling Mortality in addition to Birth?

Gracia, et al., 2010 (ISWC, LNCS 6414)
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Consistency-based Diagnosis

Conflicts

{A1, M1, M2}  {A1, M1, A2, M3}

Candidates

Single faults: {A1} or {M1}  (also multiple faults: {A2, M2})

Measuring

E.g. value at Y (or X)
CBD in technical context

Created by designer

Blue print (design)

Component model

Device

Measure

GDE

Diagnosis

Incorrectly behaving component

Probe
CBD in learning context

- Model
- Simulation results of model
- Simulation results expectations
- Created by Learner
- Expressed by Learner
- De Koning et al, 2000 (AIJ)
- Incorrect model ingredient
- Probe
- Measure
- GDE

De Koning et al, 2000 (AIJ)
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Feedback & Character roles

- Basic help (what is, how to, ..)
- Advanced help (model diagnosis)
- Model comparison
  - Recommender and/or Critic
- Teachable agent
- Quiz

Initiative always with the learner!
Concluding remarks

• Problem statement and Context
  – Communicative interaction (science education)
• Knowledge representation and Reasoning
  – Qualitative system dynamics / Conceptual knowledge
• Progressive learning spaces (6 spaces)
• Feedback for Reflective thought
  – Semantic Web techniques (model ingredients)
  – Consistency-based Diagnosis (simulation results)
• Inducing Motivation (virtual characters & modes)