An intelligent learning environment for learning conceptual knowledge

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Overview

• Problem statement and Context
• Knowledge representation and Reasoning
• Progressive learning spaces
• Feedback for Reflective thought
• Inducing Motivation using Virtual characters
• Educational embedding
• Concluding remarks
What happens? Why?

- **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**

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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.

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…
Problem statement

• Worrying decline in science curricula
  – Less students sign up
  – More students drop out
• Main reasons
  – Lack of engagement and motivation in science teaching
  – Lack of tools to interactively construct conceptual knowledge

How to address these using:
Technology-Enhanced Learning (EC-TEL)

e.g. Osborne et al. 2003
DynaLearn - Main objective

• To develop an interactive learning environment that allows learners to construct their conceptual system knowledge.

- Reflective interaction with virtual characters
- Feedback generators:
  - Semantic technology
  - Model diagnosis

- Applied to (environmental) science education
- Secondary & Higher education
To develop an interactive learning environment that allows learners to construct their conceptual system knowledge.

- Reflective interaction with virtual characters
- Accommodate the true nature of conceptual knowledge
- React to the individual knowledge needs of learners
- Workspace for interactive knowledge constructing
- Feedback generators: - Semantic technology - Model diagnosis
- Be engaging by using personified agent technology

- Applied to (environmental) science education
- Secondary & Higher education

DynaLearn - Main objective

Integrate proven technology

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Qualitative Reasoning Engine

- Multiple domains (e.g. Physics, Ecology, Economics, ..)
- Multiple tasks (Education, Device diagnosis, Robotics navigation, ..)

Library of model fragments

Scenarios
Initial values
Assumptions

Qualitative reasoning engine

Behavior graph

Transition rules

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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
Scenario *(Starting situation)*

- Generic vocabulary
- Visualisation
- Domain facts

**Population**

**Green frog**

**Number of**

Current value

Possible values

Generic class

Specific instance

Quantity

Derivative *(direction of change)*

Zsml
- Large
- Medium
- Small
- Zero

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Qualitative Reasoning Engine

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

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Capturing partial knowledge

Influence:
The amount of Birth increases Number of

Proportionality:
Changes in Number of determine changes in Birth

Mathematical foundation

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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
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Qualitative reasoning engine

Library of model fragments

Behavior graph

Transition rules
Simulation
Simulation results

State-graph & Behaviour Paths

State-graph

Behaviour path

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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.

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Progression of Learning Spaces

1. Concept
   - Node
   - Arc

2. Structure / Behaviour
   - Entity / Quantity
   - Causal change
     - Pos / Neg

3. Landmark
   - Quantity space
   - State graph

4. Causal differentiation
   - Influence (rate)
   - Proportionality (st var)
   - Exogenous

5. Conditional knowledge
   - If .. THEN ..

6. System independency
   - Scenario
   - Knowledge fragments

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Learning space 2: Basic causal model

What constitutes the system?
*Structure vs. behaviour*

How do changes propagate through the system?
*Positive / Negative causal dependencies*
LS2 - Causal model (Building)
LS2 - Causal model (Simulating)
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
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Generating feedback

http://dbpedia.org/resource/Mortality_rate
http://dbpedia.org/resource/Population
http://dbpedia.org/resource/Size

Semantic repository

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Model ingredients

Suggested DBpedia terms

Description

Occurrence in models

Corrections

Synonyms

Death is the termination of the biological functions that define a living organism. It will eventually afflict all living things. Death refers both to a particular event and to the condition that results thereby. The true nature of the latter has, for millennia, been a central concern of the world’s religious traditions and of philosophical enquiry. Belief in some kind of afterlife or rebirth is a central aspect of many religious traditions. Phenomena which commonly bring about death include predation (for non-human species), malnutrition, disease, or accidents resulting in terminal physical injury. When species come into conflict, extinction, the death of all members of one species occurs. Human activity has, in recent times, a
Generating feedback

- Students receive feedback on their models.
  - Example: "You can complete your model with a P+ proportionality."

- Recommendations are based on feedback from experts.
  - Example: "Users who modelled death also modelled birth."

- Community of users contributes to feedback generation.

Gracia, et al., 2010 (ISWC, LNCS 6414)
Missing negative influence

Number of models involved

Models with same feedback

User feedback

Corrections suggested

Description

The quantity 'Death' of the entity 'Population' should have a negative influence to the quantity 'Number of' of the entity 'Population'.

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Feedback & Interaction

Using animated virtual characters

What is? Explain: Model Ingredients

How to? Explain: User-Interface

Why? Explain: Occurrence of value changes

Recommendation
Compare to other models & suggest changes in Model Ingredients

Diagnosis
Bridge discrepancy between expected and actual Simulation Result

Special interaction modes:
• Teachable agent
• Quiz using existing model
Feedback & Interaction

What is? Explain: Model Ingredients

Recommendation
Compare to other models & suggest changes in Model Ingredients

How to? Explain: User-Interface

Diagnosis
Bridge discrepancy between expected and actual Simulation Result

Why? Explain: Occurrence of value changes

Special interaction modes:
- Teachable agent
- Quiz using existing model

Mehlmann, et al., 2010 (IVI, LNCS 6356)

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Teachable agent (TA)

- Teach character by creating a model
  - Learners learns by teaching
- Why?
  - Gain different perspectives on same subject
  - Designed to have a low competency
  - Induce motivation, self-efficacy and self-confidence
- Character can (based on the knowledge gained)
  - Answer prediction questions
  - Explain predictions
  - Take a challenge (quiz)
Demo – Teachable agent (TA)
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Project Partners

UVA (Netherlands)  TAU (Israel)
UPM (Spain)  UH (UK)
UAU (Germany)  IBER (Bulgaria)
FUB (Brazil)  BOKU (Austria)

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Educational embedding

- Curriculum opportunities (what? where? how?)
- Course materials
  - Explanatory models for repository
  - Assignments (fully build, repair, augment, analogy)
- Evaluation studies
- Research questions
  - Does the QR meta-vocabulary provide an analytic instrument for learners to learn (better)?
  - Do the virtual characters induce the ‘involvement momentum’?
  - Do the feedback instruments adequately support learners in acquiring the subject matter?
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Concluding remarks

- DynaLearn develops tools to facilitate educational research, with four key aspects:
  - Workspace for constructing conceptual knowledge
  - Intelligent feedback for reflective thought
  - Induce motivation using virtual characters
  - Applied to (environmental) Science Education

*Ultimate research question:* Under which conditions will learners be more motivated and achieve more?
Sabbatical Acknowledgement

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