Knowledge design centred for TEL systems

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Introduction

- Knowledge design centred is not new
  - 1980.. (Expert systems, Student modelling, diagnosis systems)

- Many European computer scientists neglected this domain because research results were not satisfactory
  - (1) negative result that error specific feedback is not more useful to the learner than generic feedback (Sleeman et al.’s, 1989)
  - (2) the intractability of student modeling (Self, 1990).

- Consequence
  - => the problem of knowledge is left to the human
Computational models and Uncertainty problem

- Trying to use first-order logic to cope with a domain such medical diagnosis fails for three main reasons:
  - Laziness: too much effort to list the complete set of antecedents or consequents needed to ensure an exception-less rule and hard to use such rules.
  - Theoretical ignorance: Medical science does not have a complete theory for the domain.
  - Practical ignorance: Even if we know all rules, we might be uncertain about a particular patient because all necessary tests have not been or cannot be run.
Interaction paradigm

1. “Classical tutoring systems” constraint the interaction
   - To tailor the environment in order to be able to give a feedback
   - If the answer is not the expected one, they give the solution

2. Classical or full scale realistic simulations are not enough to provide efficient learning environments
   1. Like we show in Kaleidoscope SEED “Learning in the medical Sector“ project (chapter 7 kaleidoscope legacy book),
   2. We need to re-think the TEL system in order to achieve adequate apprenticeship realism and to organize the feedback which is linked to an interpretation of the user’s actions in terms of used knowledge.
TEL Theoretical context

Objective is to take into account the knowledge representation in a different way:
- To understand the coherence of the learner’s solutions and processes
- To provide relevant feedback, linked to the knowledge at stake

Consequences:
- A model of the domain knowledge
- A model of diagnosis
- A model of the didactic decision

from a didactic analysis to data collection
The quality of a didactical system depends on its capacity to deliver both an epistemic feedback & a didactical feedback.

Didactical feedback

Objective:

It's necessary to choose the relevant Computer Model (symbolic vs. numeric).
Use Bayesian Network for model the uncertain dimension

Three stages
1. Variables identification and their possible values
2. Graph structure
3. Condition probability

Three types of construction in our TEL systems
1. Expert centric
2. Efficiency centric
3. Data centric

Example from Charneau et al., 2005
Computer methodology used for TEL knowledge design

1. Expert centric design
   - Few data to start
   - Based on cognitive (didactical) analysis
   - Two kind of experts: domain and didactic

2. Refine with Data centric design
   - Data can be used to learn the model, and then the expert can “fine-tune” the news version.
   - Define data collection

3. Iterative methodology
   - Integration of new forms of knowledge
The expert model, a didactical model
two cases examples

- Ilio-sacral screw fixation

- Plane take off phase

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The expert model, a didactical model

A conception is:
- a set of related problems (P),
- an associated representation system (L),
- a set of operators to act on these problems (R),
- a control structure (Σ).

ck¢ model Balacheff 1995,2003
Problems (P) and Representation

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P = Didactic variables (type of fracture, bone quality…)
P = Didactic variables (land state, length)

R = representation system

Vadcard et all 2005

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Teleos Operators (R), for P₁

Choose entry point

Choose orientation

Progression, 1st step (stop bone contact)

- verification (profile)

Progression (stop aplomb upper sacral foramen)

- verification (inlet+outlet)

Progression (stop 1cm afterwards upper sacral)

- verification (any radio)

Brit-Air Operators (R) for P₃

- limitations of the second and final segments

- the certification limitations

- the obstacle limitations

- the choice of “bracage”

Controls about the X-ray quality:
- An inlet view must show the anterior part of the sacrum
- An inlet view must show the sacral plate

Controls about the pin position:
- The pin must be behind the anterior cortical of the ala sacralis
- The pin must be in front of the sacral foramen

Vadcard et all 2005
Formalization

**Controls (Σ) : knowledge elements / validate resolution steps**

- **Entry point position:**
  - The entry point lies in the dorso-caudal quadrant, defined by the lateral and longitudinal projections of the sacrum

- **Body / X-rays correspondence :**
  - If the pin is too low on the inlet X-ray, then it is too anterior (ventral) on the patient
  - The discrepancy between two entry points on the skin is less important than the discrepancy it provokes at the level of the bone entry points (due to the grease thickness)

- **Pin’s progression:**
  - A spontaneous movement of the patient’s foot during the pin’s progression is the indication of a neurologic injury
  - Passing through a cortical provokes a more difficult progression of the pin

Declarative  Pragmatic  Perceptual & gestural

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Vadcard et all 2005
The bayesian network in TELEOS

Representation = Radios (Inlet, Outlet, Profil)

Didactical variables

Problems

Actions

Controls

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Luengo et all. 2006
Si la broche est en dessus du corps de S1 sur le profil alors elle est trop crâniale sur le patient.

Chieu et all. 2006

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Diagnosis result

Probability vector of control$_6$

\[ P(MJV) = 73\% , P(MJIV) = 11\%, P(PMJ) = 16\% \]
But after the diagnosis

- **Several systems:**
  - Inform the human with a diagnosis
  - Propose a direct feedback for each diagnosis
    - If diagnosis=X then feedback=Y

- **Few systems propose a computational model which describes the decision of a pedagogical feedback following a diagnosis**
  - Diagnosis strategy (refine the diagnosis)
  - *Decision-Theoretic Pedagogical Strategies*
**Decision-Theoretic Pedagogical Strategies**

- Systems select tutorial actions (or feedback) that maximise expected utility
- Expected utility calculation: likely outcome of the feedback, and its pedagogical utility
  - in CAPIT system (Mayo et al. 01), the expected utility of a feedback (e.g. problem selection) depends on the likely outcome of the action (e.g. how many errors are made).
- The impact of the feedback could be calculated with some type of factors
  - In DTTutor (Murray et al 01), the feedback impact on many different factors related to the student (e.g. their morale, attention,..) has an influence on the expected utility.
**Computer feedback model:**

**Decision-Theoretic Pedagogical Strategies**

- In these systems, the decision doesn’t take into account the relation between the knowledge domain and feedback strategies.
  - For example, the feedback models don’t take into account the form or the knowledge (declarative, procedural, etc.)
Teleos didactic decision model (DTP technique with knowledge factors).

- Extension of BN, three types of nodes
  - Chance nodes: represent random variable
  - Decision nodes: represent points where decisions maker has a choice of actions
  - Utility nodes or utility function.
    - Function that maps from states to real numbers

- In TELEOS Utility decision factors:
  - State of knowledge diagnosed:
    - Used valid,
    - Used invalid,
    - Not used.
  - Knowledge characteristics:
    - Type, Order, Nature

Influence diagrams

Which knowledge element is the most relevant to focus on.

Alchawafa et all 2007
1. Choose the target
2. Choose the learning objective
3. Choose the feedback form
4. Choose the feedback content

If the learning objective is verify and the target knowledge is pragmatic, then choose to solve a problem where the didactical variable type bone = hard bone...

Alchawafa et al. 2007
Tools for didactical decision validation

Parameters

- Parameter les variables pour le calcul de l'utilité
- Paramétrer les zones de l'objectif
- Paramétrer le choix de la forme
- Construire le diagramme d'influence
- Tester la procédure

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Tools for didactical decision validation

Controls characteristics

Diagnosis

Feedback Results

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From expert centric model to data centric model

- **Refine computer knowledge models from data**
  - Knowledge elements (controls, operators, ..)
  - Conditional probability between knowledge nodes
    - Causal probability between operators and controls

- **Data characteristics**
  - Computer data from activity (simulator, microWorld, scenarios ..)
  - Videos (operating room, classroom, ..)
  - Data annotated by cognitive (psychology, didactic) experts
Computer feedback validation

- Expert centric validation (Gold standard validation, Russel et al. 2003)
  - Set scenarios with input and output (student diagnosis, feedback)
    - in TELEOS: all parameters are significant but some are missing (temporal feedback dimension)

- Data centric Validation (sensitivity analysis, Russel et al. 2003)
  - With simulated data
    - in TELEOS: check whether the best decision is sensitive to small changes in the assigned probabilities and utilities
  - With real data
    - In KAL experimentations with TPelec scenarios (Michelet et all. 06) we validate the impact of remediation feedback (Michelet et all. 06). We analyse the path and the answers of all the students.
    - 118 cases with different students, 3 categories:
      - not relevant: the answer and the argumentation given by the student are the same as the first time.
      - relevant and correct.
      - relevant and incorrect. \[77\%\]
Iterative dimension
Example, take into account the perceptual knowledge
Iterative dimension, take into account the perceptual knowledge

- Same knowledge model
- Same computational models
- New interaction devices
  - Haptic feedback
  - Audio feedback
  - ...
- New data sources

<table>
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<th>TELEOS, Technical possibilities of data collection</th>
<th>Ecological</th>
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<tr>
<td>Classical surgery</td>
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<td>• screen captures</td>
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<td>• eye-tracker</td>
<td>• goniometers/accelerometers</td>
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<td>• record of physical actions (pressure, torque) on the surgical tools (if technically possible)</td>
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Conclusion and perspectives

- Relation between knowledge characteristics and their computational models
- Refine computer knowledge models
  - From expert centric models to data centric models
- Iterative techniques for update the properties of the computational model of knowledge
- Need specific process and computer models
  - Epistemological level: support the didactical design to extract and formalize knowledge
  - Computational, Artificial Intelligence algorithms for:
    - automatic transformation from cognitive analysis to computational models (diagnosis and feedback)
    - Automatic data learning for refine process

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Thank you..