A Constraint Satisfaction Based Approach to Clinical Practice Guidelines

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Outline

• Clinical practice guidelines (CPG)
  • What they are, why they are used
• Representation of CPGs
• CPG as a constraint satisfaction model
  • Three step approach
• Future works
Clinical Practice Guidelines

- IOM Study in 2001 pointed to the occurrence of large numbers of medical errors.
- CPGS are "systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances."
- CPGs Emerged out of need to reduce variability, control costs, improve outcomes.
Clinical Practice Guidelines cont.

- Need a means of implementing CPGS in day to day practice settings
- Since 2000 much of the research using CPGs has been on guideline modeling formalisms for computer based implementation
- InterMed collaboration of research groups at Harvard, Columbia and Stanford Universities
- http://www.openclinical.org/gmmsummarie s.html
Guideline Modeling Languages

• Represent processes/states through **primitives** – action step, decision step, case step
• A **process model** determines factors such as temporal order or nesting of guidelines
• Underlying **data model** that provides the detail or domain knowledge for the guideline
Table 1. Representation primitives for actions, decisions, patient states, and execution states in the reviewed guideline representation models.

<table>
<thead>
<tr>
<th>Guideline Models</th>
<th>Actions</th>
<th>Decisions</th>
<th>Patient States</th>
<th>Execution States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arden Syntax</td>
<td>action slot</td>
<td>logic slot</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>DILEMMA/PRESTIGE</td>
<td>protocol</td>
<td>state transition</td>
<td>n/a</td>
<td>procedure state</td>
</tr>
<tr>
<td>EON/DHARMA</td>
<td>action, activity</td>
<td>decision</td>
<td>scenario, activity state</td>
<td>no*</td>
</tr>
<tr>
<td>PROforma</td>
<td>action, enquiry</td>
<td>decision</td>
<td>n/a</td>
<td>task state</td>
</tr>
<tr>
<td>Siegfried</td>
<td>recommendation</td>
<td>logic</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>GLIF</td>
<td>action step</td>
<td>decision step</td>
<td>patient state step</td>
<td>no*</td>
</tr>
<tr>
<td>Azbru</td>
<td>plan</td>
<td>condition, preference</td>
<td>temporal patterns</td>
<td>plan state</td>
</tr>
<tr>
<td>GUIDE/PatMan</td>
<td>task, wait, monitor</td>
<td>decision</td>
<td>(implicit in Petri Net)</td>
<td>n/a</td>
</tr>
<tr>
<td>PRODIGY</td>
<td>action, activity</td>
<td>decision</td>
<td>scenario</td>
<td>n/a</td>
</tr>
<tr>
<td>GASTON</td>
<td>action</td>
<td>decision</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Torino</td>
<td>work action, query action</td>
<td>decision action</td>
<td>conclusion</td>
<td>n/a</td>
</tr>
</tbody>
</table>

n/a: information not available from the publications

§ EON/DHARMA and GLIF has execution states, but they are not in the guideline representation model
GLIF in Protégé-2.1
Issues with CPGs

- More attention has been paid to representing CPGs as models then to implementing them clinically
- Waitman and Miller 2004 – representation in computer readable format is not the main task – A Gap exists between guidelines and implementation
- How to allow guidelines to support more detailed levels of practice and also different levels of decision making expertise?
- Data issues such as uncertainty or missing data?
CPG as a constraint satisfaction model

- Extend existing research by creating a data driven approach to CPGs that represents a CPG as a constraint satisfaction model
- Constraints define allowable clinical variable values and permitted combinations of values for variables from a CPG
- Incomplete clinical data is input to a constraint model and extended to a complete CPG solution for a patient state
- Our approach addresses shortcomings in existing CPG research, in particular how to deal with missing or mismatched data
CAEP Pediatric Asthma CPG

- Created to determine severity of asthma exacerbation (mild, moderate, severe) using 8 clinical signs and 3 clinical measurements.

- **Issue:** how to apply asthma CPG in light of incomplete patient data (incomplete solution)?

- **Example:** only 5 assessments are collected and diagnostic decision of mild exacerbation is made:

  Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent),
  Typical_episode(worse)
  Exacerbation(mild) – provisional diagnosis
CSP Model Development

- Variables and their domains
  
  Dyspnea [exertional, at_rest, labored], Beta_agonist [good_response, partial_response, weak_response, no_response], Difficult_speech [absent, moderate, present], Tachycardia [absent, present], etc.

- Constraints
  
  • Unary partial-patient-descriptor: Dyspnea(exertional) AND Exacerbation(mild)
  
  • Complete-patient-descriptor: Dyspnea(at_rest) AND Beta_agonist(partial_response) AND Difficult_speech(absent) AND Tachycardia(absent) AND Tachypnea(at_rest) AND Accessory_muscules(none) AND Breathing_sounds(reduced) AND Typical_episode(same) AND SaO2(92_95) AND PEV(50_75) AND FEV(50_75) AND Exacerbation(moderate)

- Feasible solution
  
  • Any set of variable-value pairs that satisfies complete-patient-descriptor constraints and includes variable-value pairs for incomplete solution satisfying any of the unary constraints
Three Step Approach – Step 1: Consistency Check

- Check if all variable-value pairs from incomplete solution satisfy unary constraints

  Typical_episode(worse) violates:
  - Typical_episode(better) AND Exacerbation(mild)
  - Typical_episode(same) AND Exacerbation(mild)

- Variable Typical_episode is removed from the incomplete solution to create revised incomplete solution:
  Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent), Exacerbation(mild)
Step 2: Solve a Model

- For revised incomplete solution we use backtracking to determine all (complete) feasible solutions

- Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent), Tachypnea(exertional), Accessory_muscles(None), **Breathing_sounds(normal)**, Typical_episode(better), SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)

- Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent), Tachypnea(exertional), Accessory_muscles(None), **Breathing_sounds(reduced)**, Typical_episode(better), SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)

- Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent), Tachypnea(exertional), Accessory_muscles(None), **Breathing_sounds(normal)**, Typical_episode(same), SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)

- Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent), Tachypnea(exertional), Accessory_muscles(None), **Breathing_sounds(reduced)**, Typical_episode(same), SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)
Step 3: Order Feasible Solutions

- Feasible solutions are ordered according to ascending conflict value for conflicting variable-value pairs determined in Step 1
  
  - Typical_episode(worse) conflicts with Typical_episode(same) and Typical_episode(better);
  
  Assuming that better>same>worse, solutions presented are:
  
  Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent),
  Tachypnea(exertional), Accessory_muscles(none), Breathing_sounds(normal), Typical_episode(same),
  SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)

  Dyspnea(exertional), Beta_agonist(good_response), Difficult_speech(absent), Tachycardia(absent),
  Tachypnea(exertional), Accessory_muscles(none), Breathing_sounds(reduced), Typical_episode(same),
  SaO2(>95), PEV(>75), FEV(>75), Exacerbation(mild)

- Ordering of solutions shows that patient with mild exacerbation is more likely to have current episode the same as typical episode from the past. Discrepancy should prompt MD to re-evaluate clinical assessments or diagnosis
Future work

- Conduct further research to develop the heuristic to rank the feasible solutions
- Apply the constraint satisfaction approach to other guidelines
- Usability studies with clinicians at CHEO
Thank you

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