Probabilistic Model Checking for Activity Recognition in Medical Serious Games

Thibaud L’Yvonnet
Elisabetta De Maria
Sabine Moisan
Jean-Paul Rigault

International Workshop on Software Engineering for Healthcare (SEH)
(An ICSE 2021 Satellite Event)
June 3rd, 2021
Probabilistic Model Checking for Patient Behavior Analysis

• **Patient Behavior**
  • Dementia related diseases
    • Mild Cognitive Impairment (MCI)
    • Serious games targeting cognitive functions

• **PRISM and Storm**
  • Probabilistic modeling language
    • Discrete Time Markov Chains
  • PCTL* (Probabilistic Computation Tree Logic)
    • PCTL formula: $P = 0.5 [X (y = 1)]$ (next time)
Serious game inspired by a neurocognitive attention test developed in the CoBTeK team (Nice, France)

**Goal:** match pictures

**Time limit:** 5 minutes

**Properties**

Is the average amount of good responses given by a patient greater than or equal to, e.g., 30?

- \( R\{"Happy\_smiley\_reward"\} \geq 30[F \text{ (location = 2)}] \)

What is the probability for a patient to choose the correct picture exactly once and to never choose a good one again until the end of the game?

- \( P =?[(F \text{ happy_smiley}) \& (G \text{ (happy_smiley} = \rightarrow \text{ (X G ! happy_smiley} \& \text{ !quit_game)}))] \)
Second Property in Storm

What is the probability for a patient to get only one good answer reward until the end of the game?

- \( P = \text{true U } \{ \text{rew{"Happy_smiley_reward"}} \leq 1 , \text{rew{"Happy_smiley_reward"}} \geq 1 , \text{rew{"Leave_game_reward"}} \leq 0 \} (\text{location} = 2) \}

Interpretation

- There is a high chance for the MCI modeled patient to get more than 30 good responses
- Patient should not behave as depicted in Property 2
Serious game inspired by a reflex test developed in the CoBTeK team (Nice, France)

**Goal:**
- Click on all targets
- Do not click on decoys

**Properties**

What is the average accumulation of good answers on targets at the end of the game?

- \( R\{ \text{“good_on_target”} \} =? [F (!\text{game_on} \& \text{next_end})] \)

What is the probability to click only when required for the game signal number \( i \)?

- \( P =? [F (\text{num_action} = i \& ((\text{prev_none} \& \text{not_click}) \mid (\text{prev_targ} \& (\text{click_fast} \mid \text{click_slow})) \mid (\text{prev_deco} \& (\text{not_click})))) \& \neg \text{transiting}] \)
Inhibitory Control Game

Results

<table>
<thead>
<tr>
<th>Property</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property 1</td>
<td>5.55</td>
</tr>
</tbody>
</table>

Interpretation

- Patient should get around 5 good actions
- In this model
  - Training phase improves patient performance
  - The fatigue impairs patient performance
## PRISM and Storm Comparison

<table>
<thead>
<tr>
<th>Game</th>
<th>Property</th>
<th>PRISM (sec)</th>
<th>Storm (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code game</td>
<td>Property 1</td>
<td>0.016</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Property 2 PRISM</td>
<td>1.92</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Property 2 Storm</td>
<td>-</td>
<td>0.28</td>
</tr>
<tr>
<td>Inhibitory Control game</td>
<td>Property 1</td>
<td>2.428</td>
<td>0.534</td>
</tr>
</tbody>
</table>

### PRISM
- Accepts most of PCTL*
- Includes several tools and is compatible with several external tools

### Storm
- Is faster to construct a model and to compute the results.
- Allows usage of rewards in formulae with P operator
Conclusion and Future Work

Conclusion

• Formal approach for activity recognition
  • Take into account behavior variability thanks to Probabilistic Markov Chains
• Comparison of 2 tools: PRISM and Storm
• Medical protocol under way (from Nov. 2020 for 10 months)

Future work

• Adjust the models with respect to protocol results and check the accuracy of properties
• Integrate this approach into a medical diagnosis system
Probabilistic Model Checking for Activity Recognition in Medical Serious Games

Thank you