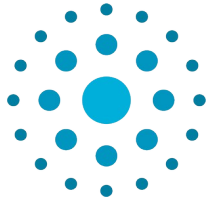

Probabilistic Model Checking for Activity Recognition in Medical Serious Games

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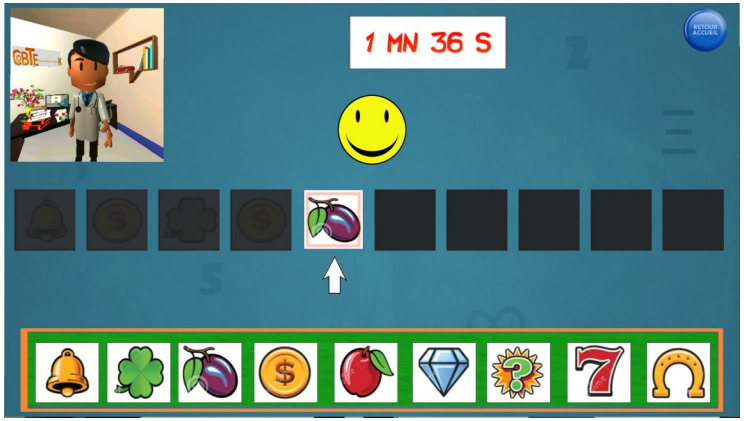
Probabilistic Model Checking for Patient Behavior Analysis

- **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)

Code Game

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"} >= 30[F (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 happy_smiley) & (G (happy_smiley =>(X G ! happy_smiley & !quit_game)))]

Code 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 =?[true U ^ {rew{"Happy_smiley_reward"} <= 1 , rew{"Happy_smiley_reward"} >= 1 , rew{"Leave_game_reward"} <= 0} (location = 2)]

Results

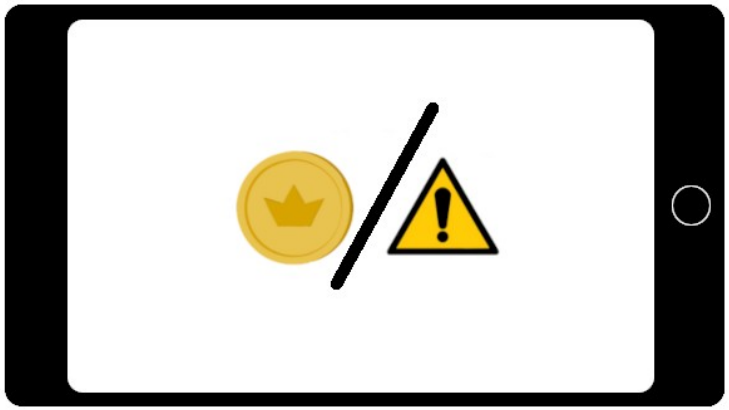
Property	Result
Property 1	true
Property 2 PRISM	1.6475 × 10 −9
Property 2 Storm	1.6475 × 10 −9

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

Inhibitory Control Game

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?

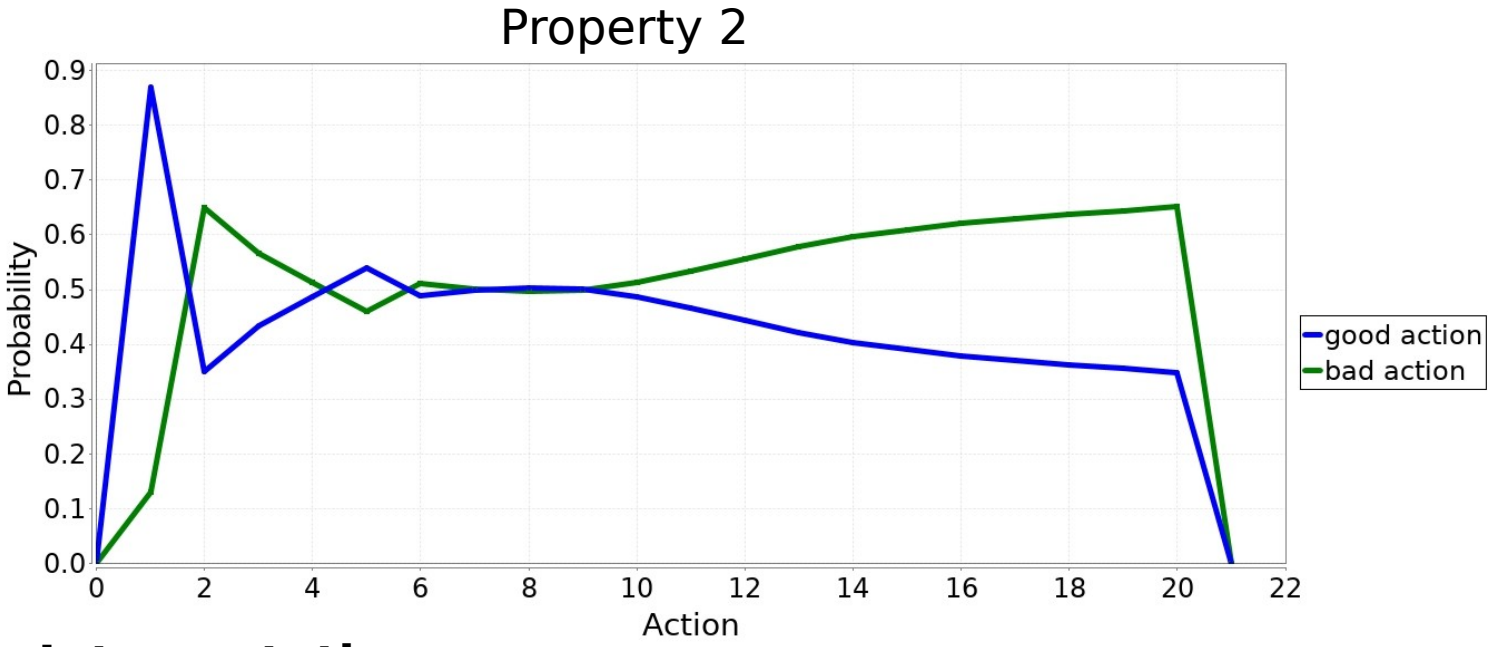
- R{ "good_on_target" } =? [F (!game_on & next_end)]

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

- P =? [F (num_action = i & ((prev_none & not_click) | (prev_targ & (click_f ast | click_slow)) | (prev_deco & (not_click))) & !transiting)]

Inhibitory Control Game

Results



Property	Result
Property 1	5.55

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

Game	Property	PRISM (sec)	Storm (sec)
Code game	Property 1	0.016	0.005
	Property 2 PRISM	1.92	-
	Property 2 Storm	-	0.28
Inhibitory Control game	Property 1	2.428	0.534

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

Thank you