Working With Probabilistic Models for Cost-Effectiveness Analysis: Computational Tools Integrating Exact Methods vs Simulation-Based Approaches

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Purpose

Monte Carlo methods are widely used for cost-effectiveness analysis, which plays a crucial role in evaluating the viability of healthcare interventions. This class of methods use statistical principles that can be applied to probabilistic models such as cost-effectiveness ones and the underlying mathematical formalisms are easy to understand. However, they present some theoretical limitation when compared to exact methods. In this study we aim to compare both approaches and analyse when each one should be applied.

Results

Monte Carlo methods can provide inaccurate results by over or underestimating outliers. Probabilistic models, combined with probabilistic symbolic model checking tools like PRISM, provide an exact approach to conduct such analyses. Moreover, PRISM syntax embeds a temporal logic language which may be used to infer properties about the model without the need of rebuilding it for that purpose.

Methods

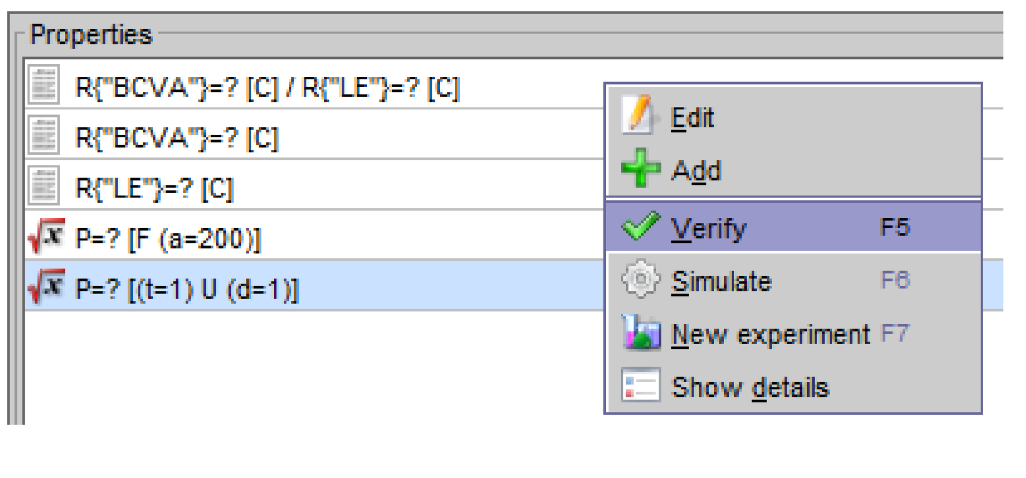
PRISM is an open-source probabilistic model checker. One describes the probabilistic model using the notion of state variable and probabilistic transition. Costs and effectiveness metrics can also be included using the notion of “rewards”.

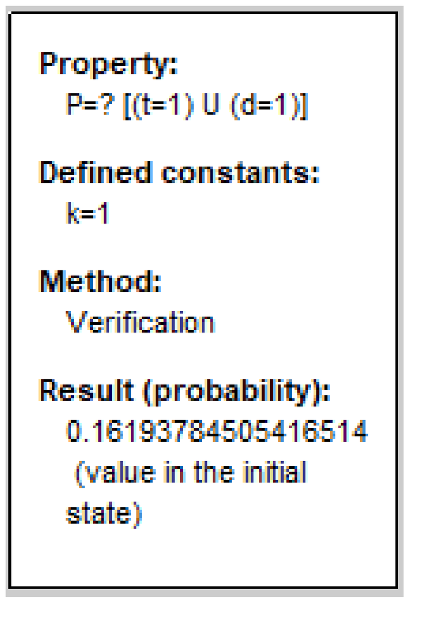
```
dtmc

const int baseline=55; // number of letter (BCVA test) and no degeneration
const int age=110 ; // age at start of treatment -> each 6-months cycle
formula death=1/(1+pow(10,2.17739-0.025683*((a/2)-59)-0.000771*pow(((a/2)-59),2))); // mortality rate (logistic regression)
const int step=9; // number of letter that patients improve in BCVA test
const int k;

module treat

        i : [0..step] init 0; // improvement
        t : [0..1] init k;// treatment

        [lab] (t=1) -> (21/397) : (t'=0) + (376/397) : (i'=step); //improve with treatment (or discountinuate)
        [lab] (t=0) -> 1 : (i'=0); //no effect without treatment

endmodule

module agingdeath

        a : [age..200] init age; //age (max: 100 years)
        d : [0..1] init 0; // death

        [lab] (d=0) & (a<200) -> death : (d'=1) + (1-death) : (a'=a + 1);

endmodule

rewards "LE" //Life expectancy
        [lab] d=0 : 1;
endrewards

rewards "BCVA" //BCVA letters
        [lab] d=0 : baseline+i;
endrewards
```

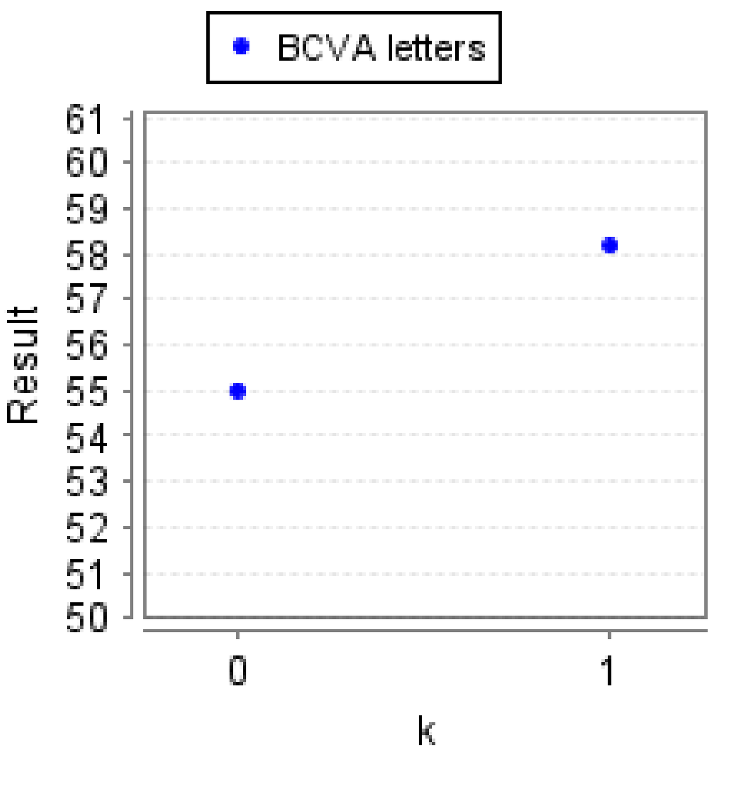
In the “properties” tab, we can easily compute the expected cumulative value for rewards. This can be applied to compute the expected total value for costs, life years, QALY or another efficacy metric.

Moreover, PRISM tools makes possible to easily compare two (or more scenarios) by labelling each one of them using a (numerical) variables.

Finally, PRISM has a language embedded. Which is based in probabilistic temporal logic syntax. By using it, we can define properties and compute the probability of their occurrence.







Conclusions

Exact tools can be useful for Health Technology Assessment since the methods underlying their functioning are more efficient than those based in Monte Carlo methods but require more computational memory. PRISM computational tool presents flexibility, enabling users to leverage both exact and simulation-based approaches, according to the complexity of the model.

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