Bayesian parameter synthesis for markov population model.

Nhat-Huy Phung

University of Konstanz

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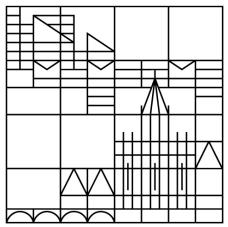
Universität Konstanz



Bayesian framework for data-informed parameter synthesis.

Model checking step

A property Φ is

- a bounded reachability property and
- specified by PCTL.

Checking a model $\mathcal{M}_\theta$ against Φ

- Rational fucntion evaluation
- Statistical model checking

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Parameter synthesis step

Algorithm 1 Markov Chain Monte-Carlo with rational functions

procedure MCMC-RF
  Init θ from prior distribution $\pi(\theta)$.
  $i \leftarrow 1$
  while $i \leq N$ **do**
    Draw θ_{cand} from $Q(\theta|\theta_1, \ldots, \theta_i)$
    if $P(D_{obs}|\theta_{cand}) > P(D_{obs}|\theta_i)$ **then**
      Accept θ_{cand} if $\mathcal{M}_{\theta_{cand}} \models \Phi$
      $i \leftarrow i + 1$
    end if
  end while
  Return $(\theta_1, \ldots, \theta_N)$
end procedure

Parameter synthesis step

Algorithm 2 Sequential Monte-Carlo with rational functions

procedure SMC-RF
  Init $\theta_1, \ldots, \theta_N$ from prior distribution $\pi(\theta)$.
  Set $w_i \leftarrow P(D_{obs}|\theta_i), 1 \leq i \leq N$
  for $t \in (1, \ldots, M)$ **do**
    Normalize $w_1^t, \ldots, w_N^t$
    Sample with replacement $\theta_1^t, \ldots, \theta_N^t$ from $\theta_1^{t-1}, \ldots, \theta_N^{t-1}$
    for $\theta_i \in (\theta_1^t, \ldots, \theta_N^t)$ **do**
      $\theta_i \leftarrow MCMC - RF(\theta_i),\ Q = F_i(\theta|\theta_1^{t-1}, \ldots, \theta_N^{t-1})$
    end for
  end for
  Return $(\theta_1, \ldots, \theta_N)$
end procedure

Parameter synthesis step

Algorithm 3 Sequential Monte-Carlo with simulations

procedure RF-SMC
  Init $\theta_1, \ldots, \theta_N$ from prior distribution $\pi(\theta)$.
  for $t \in (1, \ldots, M)$ **do**
    Sample with replacement $\theta_1^t, \ldots, \theta_N^t$ from $\theta_1^{t-1}, \ldots, \theta_N^{t-1}$
    for $\theta_i \in (\theta_1^t, \ldots, \theta_N^t)$ **do**
      Draw θ_{cand} from $F_i(\theta | \theta_1^{t-1}, \ldots, \theta_N^{t-1})$
      if Statistical Model Checking $\mathcal{M}_{\theta_{cand}} \models \Phi$ **then**
        Simulate D_{sim} from $\mathcal{M}_{\theta_{cand}}$
        if $Distance(D_{sim}, D_{obs} < \epsilon)$ **then**
          Update $\theta_i \leftarrow \theta_{cand}$
        end if
      end if
    end for
  end for
  Return $(\theta_1, \ldots, \theta_N)$
end procedure

Evaluation

Statistical Model Checking (SMC) is a formal verification technique that combines simulation and statistical methods for the analysis of stochastic systems. [1] Statistical Model Checking verifies a system S property ϕ over a finite set of *traces*, acquired through simulating the system of concern S.

Advantages

- **Scalability**: avoid state space explosion issues.

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