

Ster Hybrid Latent state models for Epidemiological and Outbreak Analysis



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Overview

Mathematical and statistical models are widely used in studying emerging infectious disease outbreaks (e.g., forecasting, planning or evaluating interventions), and yet, we have relatively little solid evidence about the comparative performance of standard computationalstatistical frameworks in these contexts. Using the classic stochastic Reed-Frost epidemic model as a baseline, we characterize and explore tradeoffs in computational efficiency and estimation accuracy among different flavours of Markov chain Monte Carlo (MCMC) estimation.

$N \sim Bin(effprop, N^*); N^* : True Pop$

N : Population

I₁: Initial Infective

p: Prob of adequate contact per I

 $S_1 = N - I_1 : \# \text{ of Susceptible at } t=1$

 $I_t \sim Bin(1 - (1-p)^{I_{t-1}}, S_{t-1})$

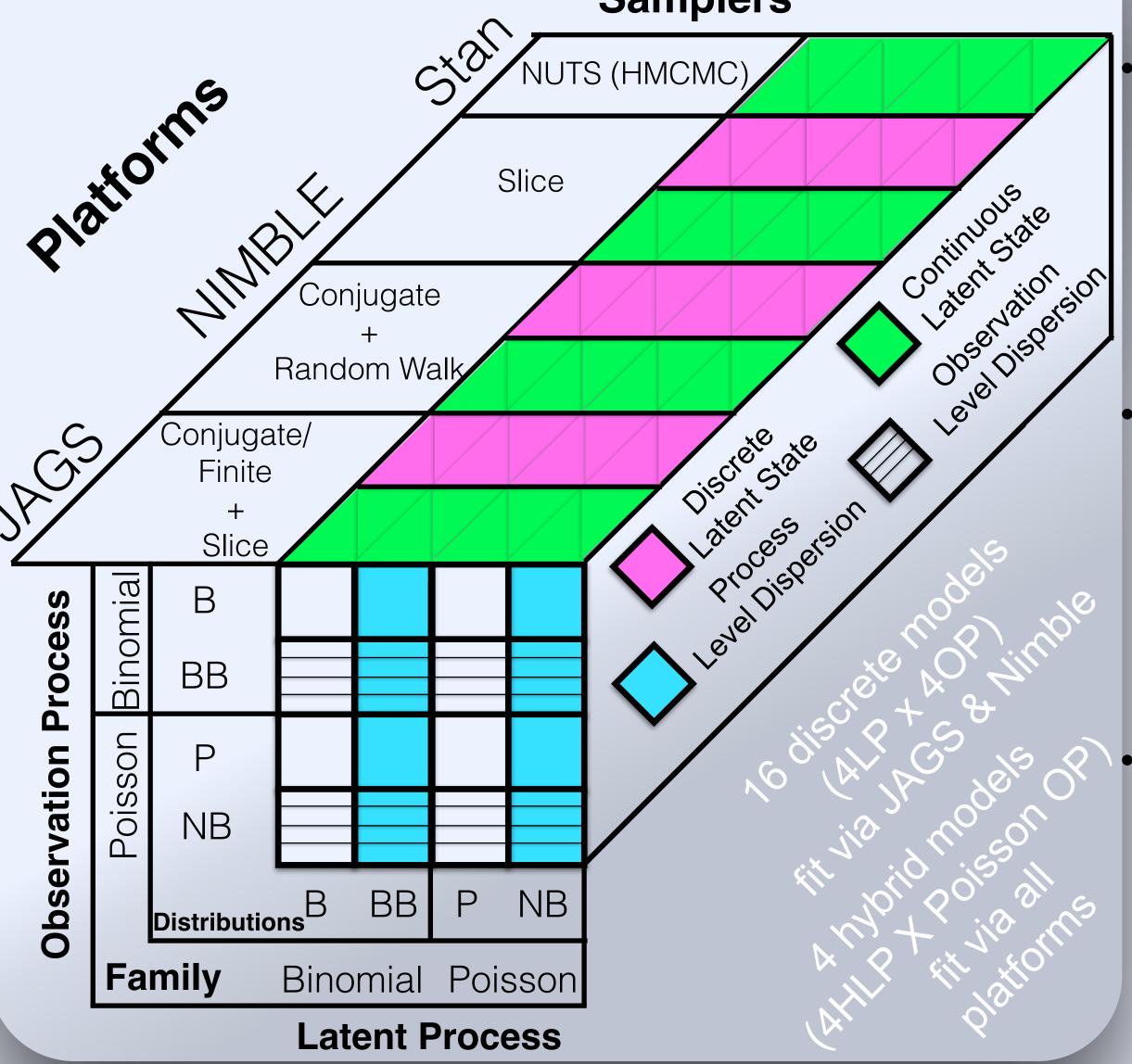
 $S_t = S_{t-1} - I_t$

Obs_t ~ Bin(r, I_t); r : reporting prob

- Reed-Frost (RF) model: discrete-time SIR model that assumes recovery one time step after infection
- We modified the R-F model as a "latent" binomial process and added an observation process with reporting prob r, and assumed N is an effective population from N*
- We used the Beta-Binomial distribution for both latent and observation level processes to generate our simulated data

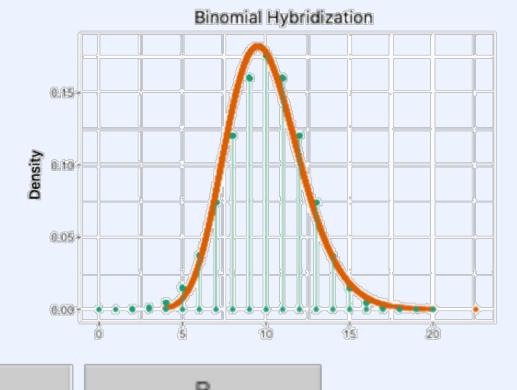
Methods

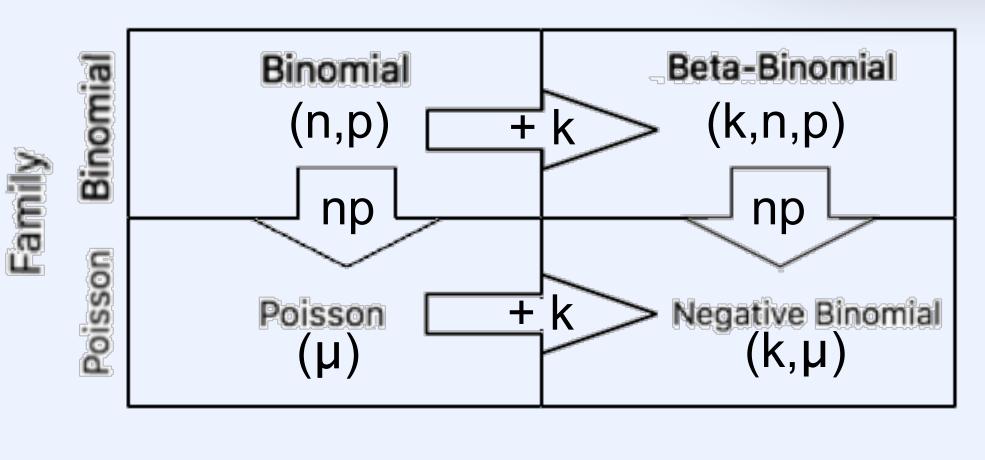
Simulation Factorial Design **Samplers**



→ BB

- JAGS uses conjugate sampling when possible, and discrete/real slice samplers otherwise.
 - NIMBLE is a more recent high performance platform that has a variety of discrete and real samplers (Random-walk (RW), RW block, slice, elliptical slice, cross level)
- Stan uses a powerful modern MCMC technique (Hamiltonian MCMC) that CANNOT be used with discrete latent states and it does not have a discrete sampler (eg. slice)
- We **hybridize** discrete distributions in the model with continuous analogues with equivalent 1st and 2nd moments



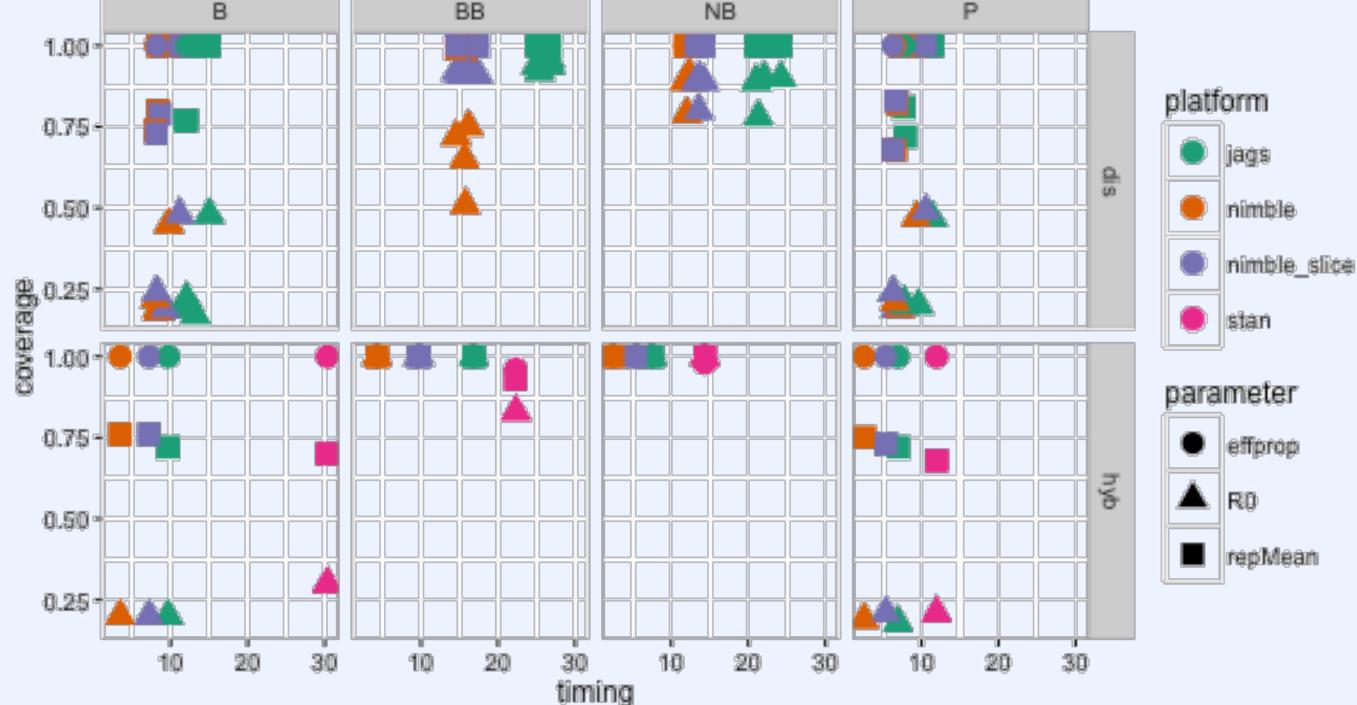


Parameters

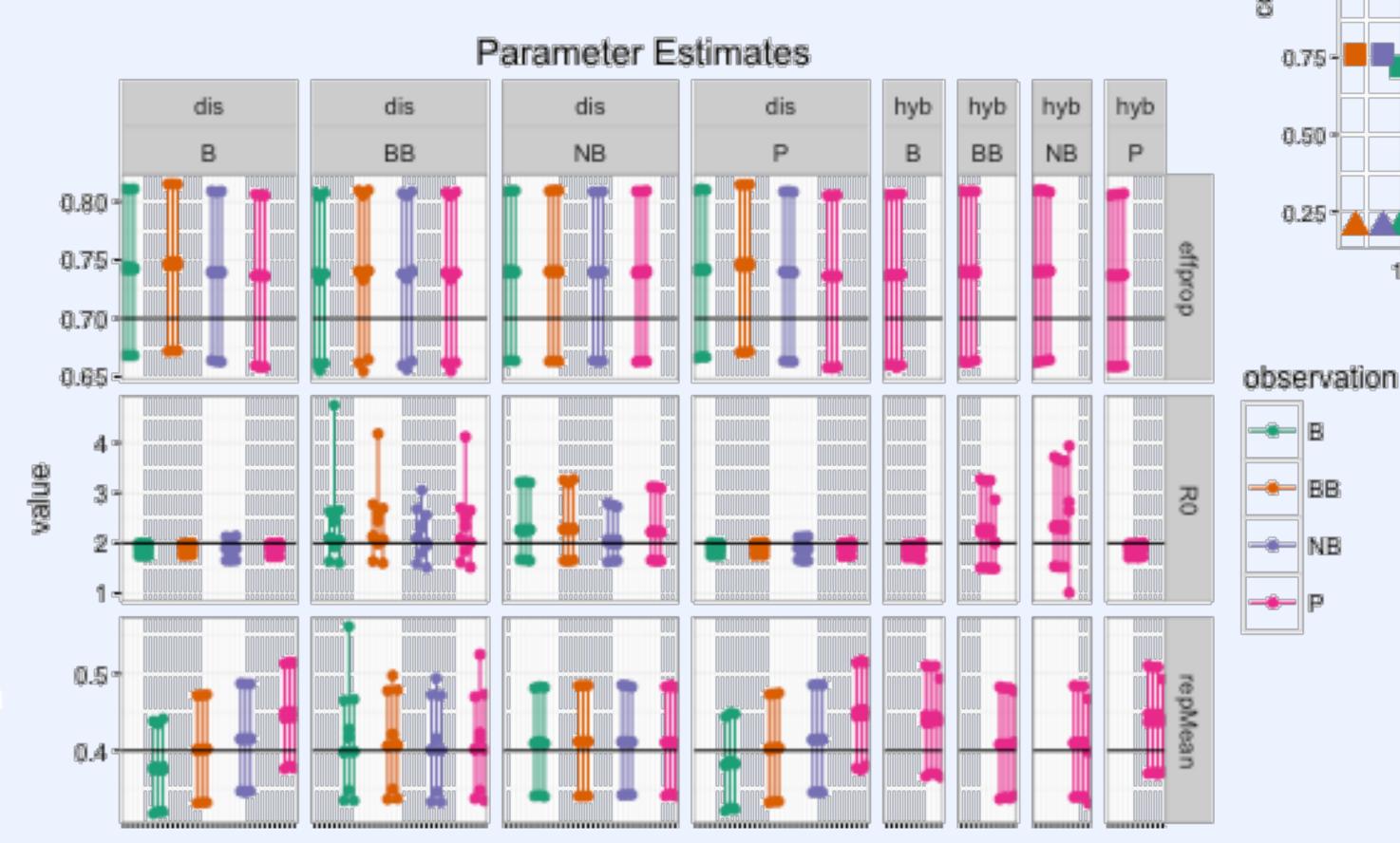
n = size

p = probability k = dispersion

 $\mu = np = mean$



Performance



Conclusion

- Hybridizing via moment matching can overcome discrete-variable obstacles
- Hybridizing also improved overall performance without losing accuracy in JAGS and NIMBLE