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**Independent sampling for Bayesian normal conditional autoregressive models with OpenCL acceleration.** (English) [Zbl 1417.65032](#)  
*Comput. Stat.* 33, No. 1, 159-177 (2018).

Summary: A new computational strategy produces independent samples from the joint posterior distribution for a broad class of Bayesian spatial and spatiotemporal conditional autoregressive models. The method is based on reparameterization and marginalization of the posterior distribution and massive parallelization of rejection sampling using graphical processing units (GPUs) or other accelerators. It enables very fast sampling for small to moderate-sized datasets (up to approximately 10,000 observations) and feasible sampling for much larger datasets. Even using a mid-range GPU and a high-end CPU, the GPU-based implementation is up to 30 times faster than the same algorithm run serially on a single CPU, and the numbers of effective samples per second are orders of magnitude higher than those obtained with popular Markov chain Monte Carlo software. The method has been implemented in the R package `CARrampsOcl`. This work provides both a practical computing strategy for fitting a popular class of Bayesian models and a proof of concept that GPU acceleration can make independent sampling from Bayesian joint posterior densities feasible.

**MSC:**

65C60 Computational problems in statistics (MSC2010)

62F15 Bayesian inference

62P10 Applications of statistics to biology and medical sciences; meta analysis

**Keywords:**

`CAR`; `CARrampsOcl`; Dirichlet density; Kronecker sum; rejection sampling; separability

**Software:**

CUDA; R-INLA; R; OpenBUGS; CARBayes; CODA; R2WinBUGS; GMRFLib; OpenCL; `CARrampsOcl`

**Full Text:** [DOI](#)

**References:**

- [1] Besag, J, Spatial interaction and the statistical analysis of lattice systems (with discussion), *J R Stat Soc Ser B*, 36, 192-225, (1974) · [Zbl 0327.60067](#)
- [2] Besag, J; Higdon, D, Bayesian analysis of agricultural field experiments, *J R Stat Soc Ser B Stat Methodol*, 61, 691-746, (1999) · [Zbl 0951.62091](#) · [doi:10.1111/1467-9868.00201](#)
- [3] Besag, J; Kooperberg, C, On conditional and intrinsic autoregressions, *Biometrika*, 82, 733-746, (1995) · [Zbl 0899.62123](#)
- [4] Bratley P, Fox BL, Schrage LE (1987) A guide to simulation, 2nd edn. Springer, New York · [Zbl 0515.68070](#) · [doi:10.1007/978-1-4419-8724-2](#)
- [5] Cowles, MK; Yan, J; Smith, B, Reparameterized and marginalized posterior and predictive sampling for complex Bayesian geostatistical models, *J Comput Graph Stat*, 18, 262-282, (2009) · [doi:10.1198/jcgs.2009.08012](#)
- [6] Cowles K, Seedorff M, Sawyer A (2013) `CARrampsOcl`: Reparameterized and marginalized posterior sampling for conditional autoregressive models. OpenCL implementation. R package version 0.1.3 · [Zbl 0805.62033](#)
- [7] Devroye L (1986) Nonuniform random variate generation. Springer, New York · [Zbl 0593.65005](#) · [doi:10.1007/978-1-4613-8643-8](#)
- [8] He, Y; Hodges, JS; Carlin, BP, Re-considering the variance parameterization in multiple precision models, *Bayesian Anal*, 2, 1-28, (2007) · [Zbl 1331.62141](#) · [doi:10.1214/07-BA201](#)
- [9] Hodges JS (2013) Richly parameterized linear models. Chapman and Hall/CRC Press, Boca Raton
- [10] Kass, RE; Gelman, A; Carlin, BP; Neal, RM, Markov chain Monte Carlo in practice: a roundtable discussion, *Am Stat*, 52, 93-100, (1998)
- [11] Kunsch, H, Robust priors for smoothing and image restoration, *Ann Inst Stat Math*, 55, 1-19, (1994) · [Zbl 0805.62033](#) · [doi:10.1007/BF00773588](#)

- [12] Laub AJ (2005) Matrix analysis for scientists and engineers. Society for Industrial and Applied Mathematics, Philadelphia · Zbl 1077.15001 · doi:10.1137/1.9780898717907
- [13] Lee D (2013) CARBayes: an R package for Bayesian spatial modeling with conditional autoregressive priors. J Stat Softw 55(13):1-24. <http://www.jstatsoft.org/v55/i13/> · Zbl 1284.62669
- [14] Lee, A; Yau, C; Giles, M; Doucet, A; Holmes, C, On the utility of graphics cards to perform massively parallel simulation of advanced Monte Carlo methods, J Comput Graph Stat, 19, 769-789, (2010) · doi:10.1198/jcgs.2010.10039
- [15] Neal, RM, Slice sampling, Ann Stat, 31, 705-767, (2003) · Zbl 1051.65007 · doi:10.1214/aos/1056562461
- [16] NVIDIA Corporation (2016) CUDA parallel computing platform. [http://www.nvidia.com/object/cuda\\_home\\_new.html](http://www.nvidia.com/object/cuda_home_new.html). Accessed 5 Aug 2016 · Zbl 0899.62123
- [17] Plummer M, Best N, Cowles K, Vines K (2008) coda: Output analysis and diagnostics for MCMC. R package version 0.13-3
- [18] R Development Core Team (2013) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>, ISBN 3-900051-07-0
- [19] Reich, BJ; Hodges, JS; Carlin, BP, Spatial analyses of periodontal data using conditionally autoregressive priors having two classes of neighbor relations, J Am Stat Assoc, 102, 44-55, (2007) · Zbl 1284.62669 · doi:10.1198/016214506000000753
- [20] Rue H, Held L (2005) Gaussian Markov random fields theory and applications. Chapman and Hall CRC, Boca Raton · Zbl 1093.60003 · doi:10.1201/9780203492024
- [21] Rue, H; Martino, S; Chopin, N, Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations, J R Stat Soc Ser B, 71, 319-392, (2009) · Zbl 1248.62156 · doi:10.1111/j.1467-9868.2008.00700.x
- [22] Rue H, Martino S, Lindgren F, Simpson D, Riebler A (2009b) INLA: Functions which allow to perform full Bayesian analysis of latent Gaussian models using Integrated Nested Laplace Approximation. R package version
- [23] Sturtz S, Ligges U, Gelman A (2005) R2WinBUGS: a package for running WinBUGS from R. J Stat Softw 12(3):1-16. <http://www.jstatsoft.org> · Zbl 0951.62091
- [24] The Khronos Group (2016) OpenCL: the open standard for parallel programming of heterogeneous systems. <http://www.khronos.org/opencl/>. Accessed 5 Aug 2016
- [25] Thomas A, O'Hara B, Ligges U, Sturtz S (2006) Making BUGS open. R News 6(1):12-17. <http://cran.r-project.org/doc/Rnews/>

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