Stan Can Use GPUs Now!

(almost!)

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June 1st, 2018

Stan has access to GPUs

- We see speedups of 8x for GPs with $N = 5000$
- Parameter estimates retain precision $\left(10^{-14}\right)$
- In production by July
- GPUs + MPI + threading is very exciting!

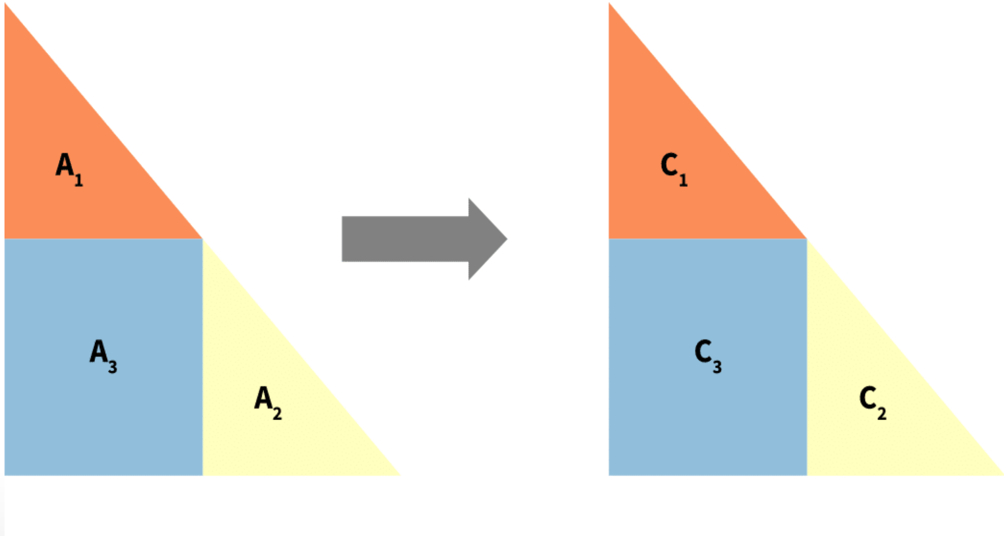
What do we have so far?

1. Matrix transpose
2. Multiplication of matrices with a diagonal and scalar
3. Addition/Subtraction of matrices
4. Copying submatrices
5. Matrix multiplication
6. Lower triangular matrix inverse
7. Cholesky decomposition
8. First derivative of Cholesky decomposition

Hows it Work? - Inverse

- Calculate $A1$ and $A2$ inverse sequentially ($C1$ and $C2$)

$$C3 = -C2 \times A3 \times C1$$

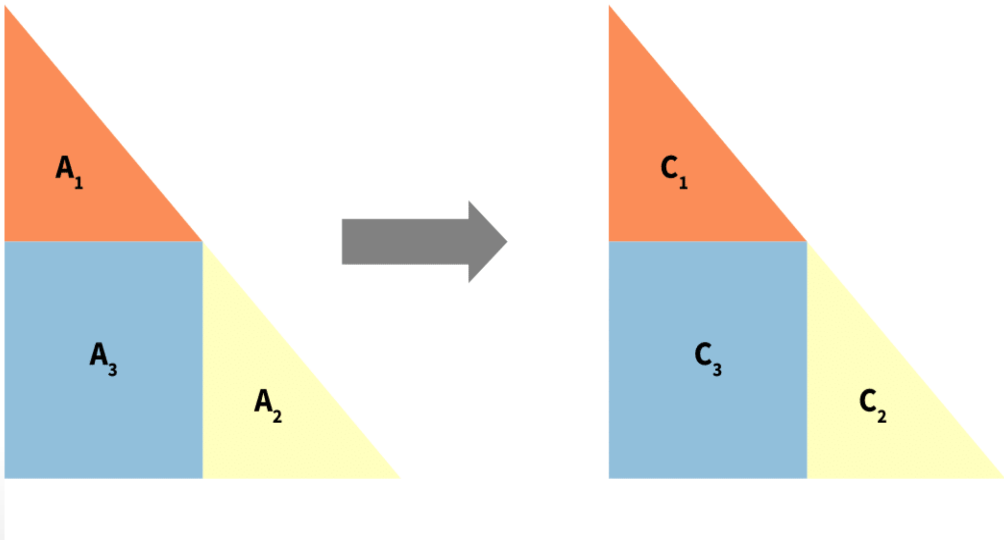


- Blocking algorithm by (Mahfoudhi, 2012)

Calculating A1 and A2 Inverse

- Calculate $A1_{A1}$ and $A1_{A2}$ inverse sequentially ($A1_{C1}$ and $A1_{C2}$)

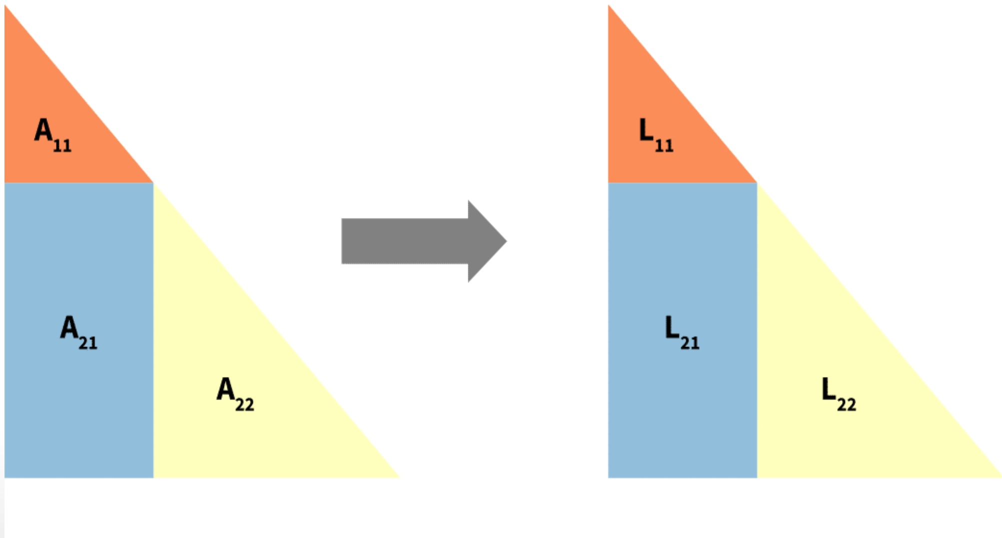
$$A1_{C3} = A1_{-C2} \times A1_{A3} \times A_{C1}$$



Hows it Work? - Cholesky

- Same as inverse, but only sequential for A_{11}

$$L_{21} = A_{21}(L_{11}^{T})^{(-1)} \qquad L_{22} = A_{22} - L_{21}(L_{21})^{T}$$



Example: 1D GP Regresssion

- Example from (Betancourt, 2017)
- Relationship between x and y with added Gaussian noise:

$$x_i \sim_{\text{iid}} U(-10, 10)$$

$$y_i | x_i \sim_{\text{iid}} N\left(f(x), \frac{1}{10}\right), i = 1..n,$$

where

$$f(x) = \beta(x + x^2 - x^3 + 100 \sin 2x - \alpha)$$

- Parameters β and α s.t. $E[f] = 0$ and $Var[f] = 1$.

Code Example

- Take Michael's code from his GP tutorial online
- replace

```
matrix[N1, N1] L_K = cholesky_decompose(K);
```

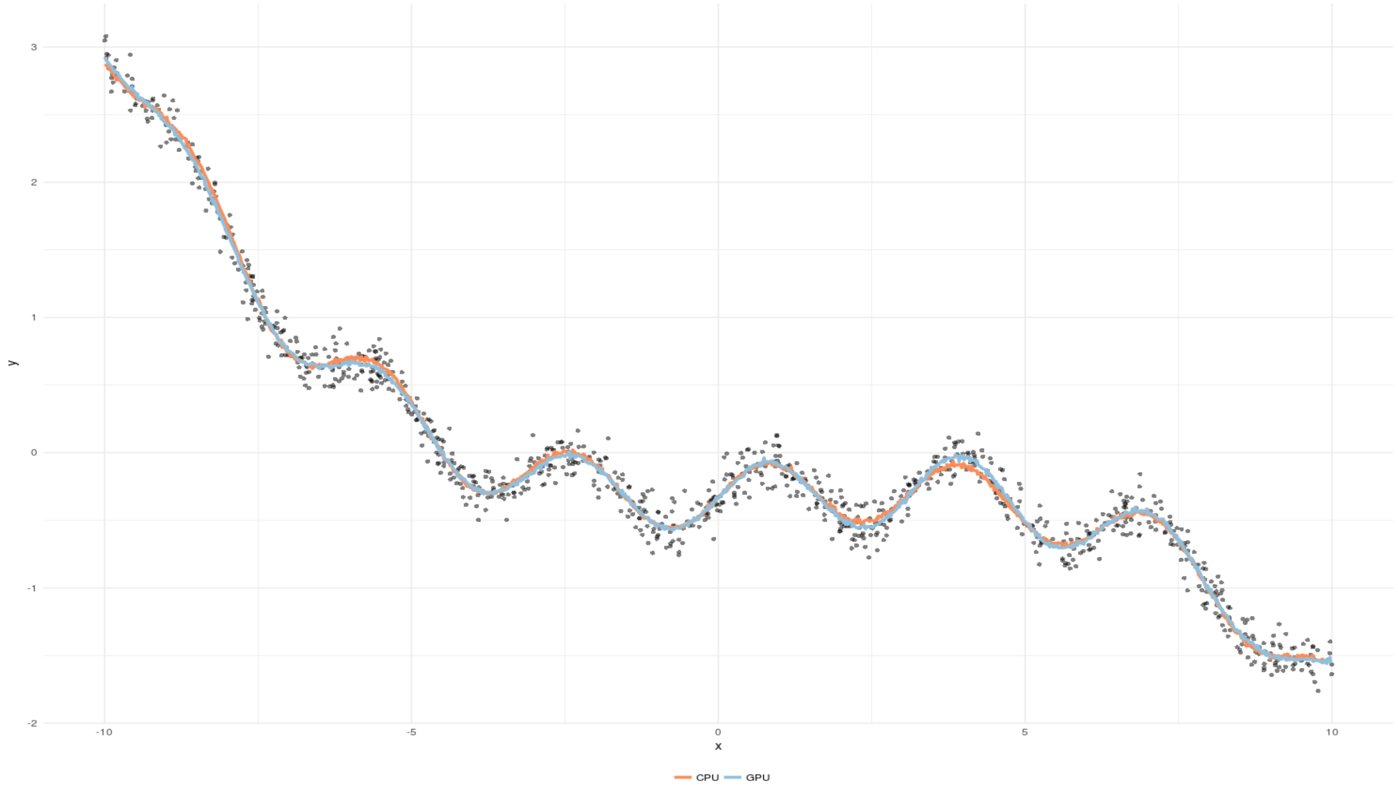
with

```
matrix[N1, N1] L_K = cholesky_decompose_gpu(K);
```

Pass compiler options:

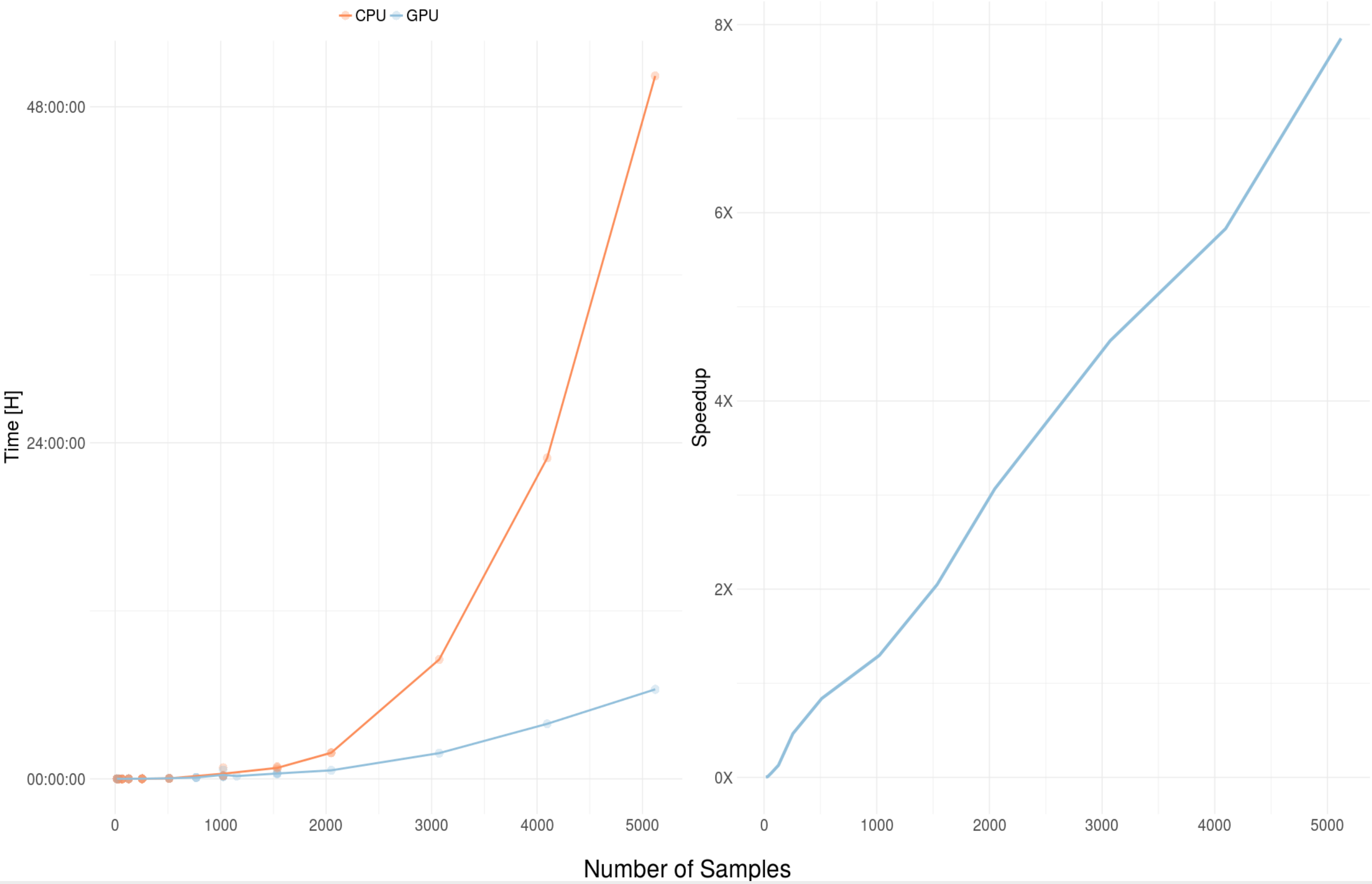
```
STAN_OPENCL=true
OPENCL_DEVICE_ID=0
OPENCL_PLATFORM_ID=0
```

How do the Samples Look?



- Pretty good!

But The Speed?



Results

- Things are fast and precise!
- We'll be wrapped up (hopefully) in July
- Email: sab2287@columbia.edu

Bibliography

Mahfoudhi, Ryma et al. “High Performance Recursive Matrix Inversion for Multicore Architectures.” 2017 International Conference on High Performance Computing & Simulation (HPCS) (2017): 675-682.

Betancourt, Michael. "Robust Gaussian Processes In Stan, Part 3". Betanalpha.Github.Io, 2018, https://betanalpha.github.io/assets/case_studies/gp_part3/part3.html.

Louter-Nool, Margreet. 1992. “Block-Cholesky for Parallel Processing.” Appl. Numer. Math. 10 (1). Amsterdam, The Netherlands, The Netherlands: Elsevier Science Publishers B. V.: 37–57. doi:10.1016/0168-9274(92)90054-H.

Slides/Paper/Code: