

Speeding up lattice QCD simulation on Arm architectures with multigrid algorithm



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Introduction

Lattice quantum chromodynamics (lattice QCD) is the non-perturbative definition of the QCD theory from first principle and can be systematically improved, meanwhile, it is one of the most important high performance computing application in high energy physics. The physics research of lattice QCD benefited enormously from the development of computer hardware and algorithm, and particle physicist can now study strong interaction at physical pion mass, smaller lattice spacing and larger volume. On the other hand, with the emerging of supercomputers and clusters based on Arm architectures, it is necessary to implement the algorithm and conduct the simulation on these machines to maximize the utilization of the limited computing resources. In this paper, we implemented and ported the multigrid (MG) algorithm, the state of the art algorithm to solve the sparse linear Dirac equation $Dx = b$ on the lattice, on a cluster with Arm based processors for clover fermion.

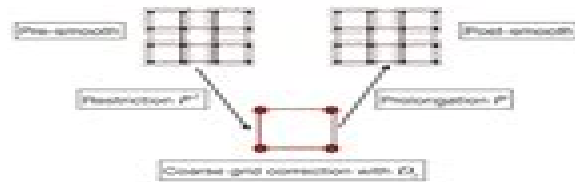
Arm architecture



- Kunpeng 920 @ 2.6 GHz
- 7nm, Arm v8.2
- 96 cores / CPU

Multigrid algorithm

- multigrid V-cycle



- generate near null vector with $Dv_1 = 0$
- construct prolongator P and restrictor R from v_1
- create coarse operator with Galerkin projection $D_c = RDP$, usually choose $R = P^T$
- use MG as preconditioner of Krylov solver (e.g., FGMRES)
- ported eg_proto² library on KNL and Intel Xeon to Arm with NEON vectorization

²https://github.com/jeffersonlab/eg_proto

Distillation method

A quark field smearing scheme, factorizing operator construction and propagator computation and large operator set can be used to do GEVP analysis.

- generate Laplace eigenvectors V
- compute perambulators $\tau_{\alpha\beta}(t', t) = V^T(t') D_{\alpha\beta}^{-1}(t', t) V(t)$
- compute elementals $\Phi_{\alpha\beta}(t) = V^T(t) [\Gamma(t)]_{\alpha\beta} V(t)$
- construct two point functions with τ and Φ s.

Large amount of $Dx = b$ solve

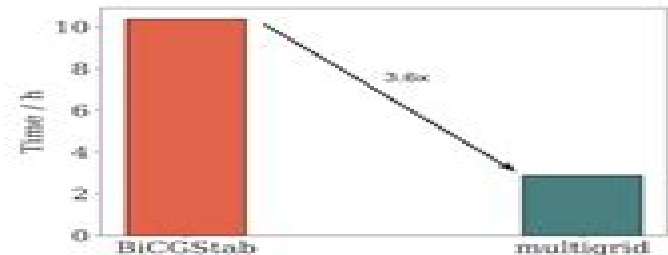
- on every configuration, $N_c \times N_{\text{spin}} \times N_{\text{vec}}$
- very suitable for multigrid especially at light quark
- reuse multigrid setup for every source b

Results

Test on $16^3 \times 128$ lattice with $m_\pi = 350$ MeV

$L^3 \times T$	β	$a_t(\text{fm})$	ξ	N_{vec}	$m_\pi(\text{MeV})$
$16^3 \times 128$	2.0	0.1517	5	70	350

BiCGStab vs. multigrid on distillation



- on single time source
- on single Kunpeng 920 node
- solve $Dx = b$ ($N_{\text{vec}} \times N_{\text{spin}} = 280$ times)
- convergence residual $1e-7$
- multigrid is 3.6x faster than biCGstab

Summary

- The state of art multigrid algorithm is ported to Kunpeng 920 CPU, a Arm based processor
- We then use the multigrid algorithm in the distillation method to compute the perambulators and gain 3.6x speed up compared to the conventional BiCGStab algorithm, on a gauge ensemble with lattice volume $16^3 \times 128$ and pion mass $m_\pi = 350$ MeV.
- We can now use the Arm cluster more efficiently and we expect further speed up when approaching to the near physical pion mass.

Contributions To Multigrid

**Todor Boyanov, Stefka
Dimova, Krassimir Georgiev, Geno
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