DEVELOPMENT OF AN OBJECT ORIENTED LATTICE QCD CODE “BRIDGE++”

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Bridge++ Project

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WHAT IS BRIDGE++ PROJECT

We are developing a lattice QCD code set Bridge++

- Project site (Now Japanese only, translating to English ):
  - [http://bridge.kek.jp/Lattice-code/](http://bridge.kek.jp/Lattice-code/)
- Core member: S.AOKI(Kyoto Univ.), T.AOYAMA(Nagoya Univ.), K.KANAYA, Y.NAMEKAWA, H.NEMURA, Y.TANIGUCHI, N.UKITA(Tsukuba Univ.), H.MATSUFURU, S.UEDA(KEK), S.MOTOKI(Aizu Univ.)
- Supported by:
OUTLINE

1. Short Introduction of Bridge++ project
2. Introduction to Lattice QCD
3. Lattice QCD common code “Bridge++”
4. Demonstration (If we have enough time)
INTRODUCTION TO LATTICE QCD
2 APPROACHES TO QCD CALCULATION

Perturbative calculation
- High energy region
- Deep Inelastic Scattering

Non-perturbative calculation
- Low energy region
- Quark confinement etc.

‘Lattice QCD’ is powerful non-perturbative method.
Field theory on 4D Euclidean lattice
Fermion: Grassmann numbers on sites
Gauge field: link variables on links
\[ A_\mu(x) \rightarrow U_\mu(x) = e^{iA_\mu} \]
Action: gauge invariant
Path integral quantization
QCD: \[ < O > = \int D\bar{\psi} D\psi DA_\mu O(\bar{\psi}, \psi, A_\mu) e^{iS_{QCD}} \]

Wick rotation, discretization

Lattice QCD: \[ < O >_{Lat} = \int D\bar{\psi} D\psi DU_\mu O(\bar{\psi}, \psi, U_\mu) e^{-S_{Lat}} \]

Integrate Fermion part

\[ < O > = \int DU_\mu O(U_\mu) \det(D_F) e^{-S_G} \]

- In numerical Monte Carlo simulations:
- Generate gauge configurations under
  \[ P(U_\mu) \propto \det(D_F) e^{-S_G}. \]
- Expectation value \[ < O > = \sum O(U_\mu). \]
LATTICE QCD

- Lattice simulation has become an important tool for nonperturbative QCD.
- Applications beyond QCD.
- Development of computer is extends research field.

- Lots of physical models
- Variety of architectures (massively parallel multi level processor, GPGPU etc.)
- Efficient numerical algorithms
WHY NEW CODE SET?

Already public code sets are available.
- CPS++, Chroma, MILC, Lattice tool kit etc.

We decided new base code set

- Friendly support and quick response.
- Collaborative development for new idea.
- Keep know-how in code developments.
CODE SET AS AN INFRASTRUCTURE

- **Readability**: easy to read and use
- **Portability**: from laptop PC to supercomputer.
- **Extensibility**: easy to test new ideas
- **High-performance**: enough performance for productive research

- Programming language: C++
  - Object oriented
  - Design patterns
- Covers wide range of architectures
  - MPI, OpneMP/pthread, OpenCL for arithmetic accelerators.
- Rich documents
OBJECT ORIENTED

- Construct parts in units of ‘objects’, which are sets of data and methods
- Separate Interface and implementation
- To maximize reusability
- To localize specific optimized(dirty) code

We repeat implementation, verification and refactoring.
We need to solve linear problem frequently, for large sparse matrix, fermion operator.

Solver class uses fermion operator class through interface.

Implement solver in inheritance classes.

Implements fermion operator in inheritance classes.
IMPLEMENTED FUNCTIONS

- Major lattice gauge/fermion actions
- Algorithms (configuration generation, linear solvers, eigenvalue problem)
- Observables (hadron correlator, static potential)
- ILDG (International Lattice Data Grid) format
- Parameters given by YAML file
- Variety of examples

Coming soon
- Multi-thread (pthread, OpenMP), GPGPU (OpenCL)
- $N_C \neq 3$, adjoint fermion representation
DOCUMENTATIONS

- First step guide/Implementation note
- Verification reports
- Doxygen document
HISTORY AND OUTLOOK

- 2009 project started
- 2012 July: ver1.0 public release. Current version is 1.0.6

Now in progress:
- Translating documents to English
- Refactoring and implementing new functions
- Optimizing to BG/Q, SR-16K, K-computer, GPU, Xeon phi

- This July we will release ver. 1.1.
DEMONSTRATION OF BRIDGE++

- HMC step with Wilson fermion and Plaquatte gauge action
Let’s start lattice QCD with ‘Bridge++’

http://bridge.kek.jp/Lattice-code/