DEVELOPMENT OF AN OBJECT ORIENTED LATTICE QCD CODE "BRIDGE++"

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Bridge++ Project

ACAT 2013 @ Beijing May 13, 2013

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/
- 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 :
  - Grant-in-Aid for Scientific Research on Innovative Areas (2008-2012) http://bridge.kek.jp/
  - Joint Institute for Computational Fundamental Science (2011-2015) http://www.jicfus.jp/
  - HPCI Strategic Program Field 5 (2011-2015) http://www.jicfus.jp/field5/

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

Perturbatvie calculation
- High energy region
- Deep Inelastic Scattering

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

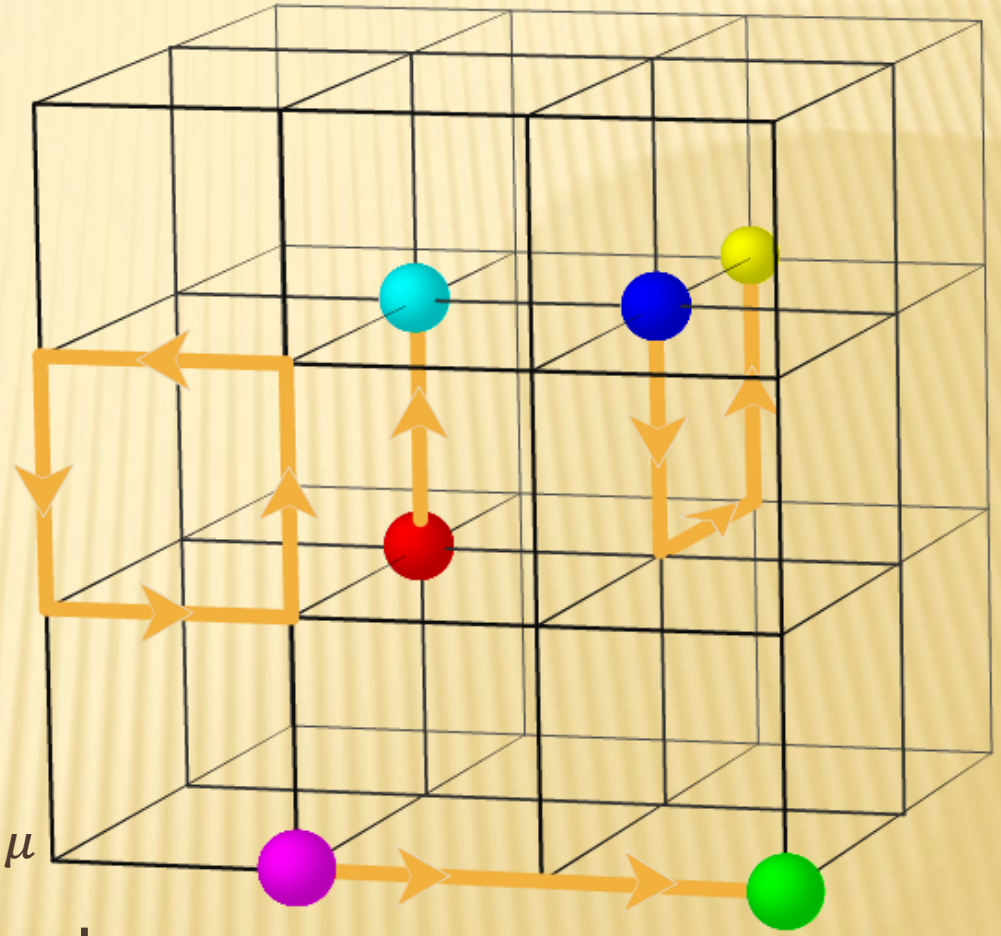
'Lattice QCD' is powerful non-perturbative method.

LATTICE QCD

- Field theory on 4D Euclidean lattice
- Fermion: Grassmann numbers on sites
- Gauge field: link variables on links

$$A_\mu(x) \to U_\mu(x) = e^{iA_\mu}$$

- Action: gauge invariant
- Path integral quantization



OBSERVABLE IN LATTICE QCD

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 nonperturabative QCD.
- Applications beyond QCD.
- Development of computer is extends research field.

- Lots of physical models
- Variety of architectures (massively parallel multi level processer, GPGPU etc.)
- Efficient numerical algorithms

LATTICE QCD COMMON CODE "BRIDGE++"

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

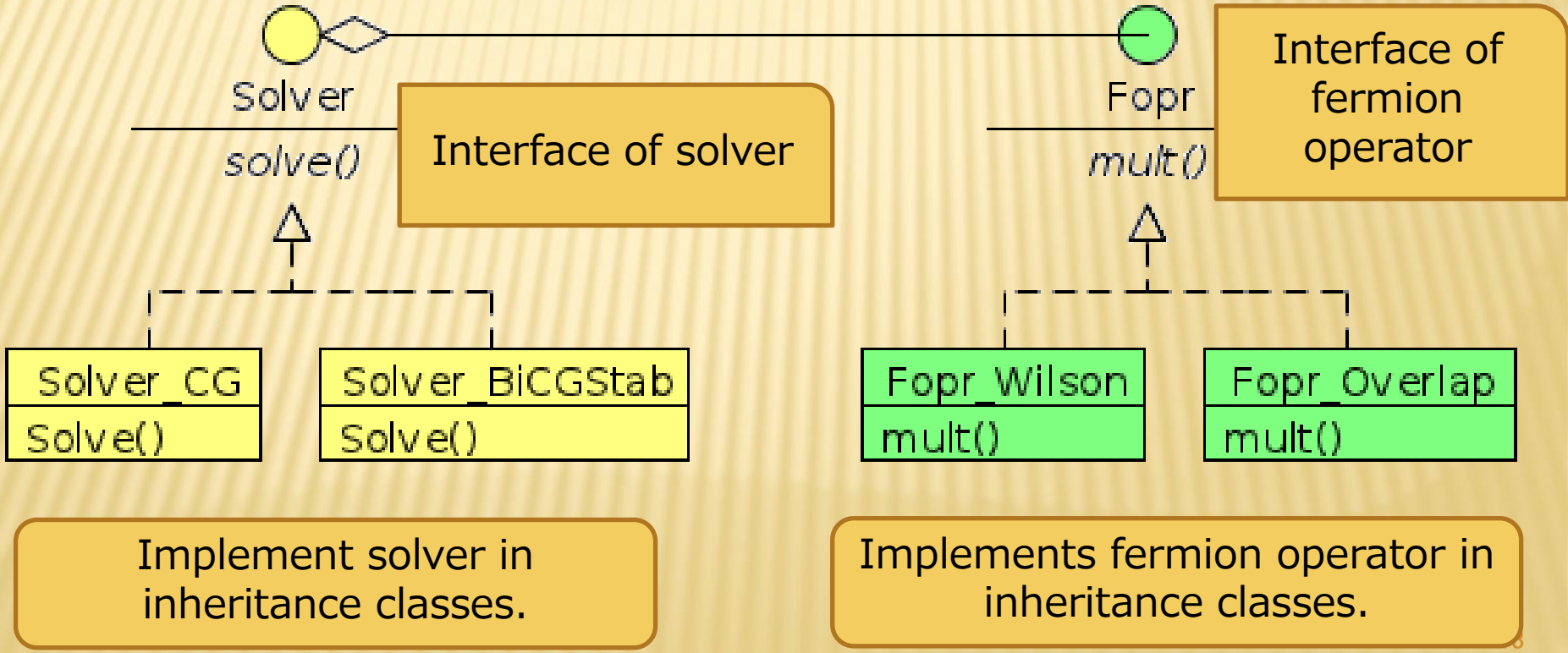
OBJECT ORIENTED

- 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.

OBJECT ORIENTED: SOLVER AND FERMION OPERATOR

- We need to solve linear problem frequently, for large sparse matrix, fermion operator.
- Solver class uses fermion operator class through interface.



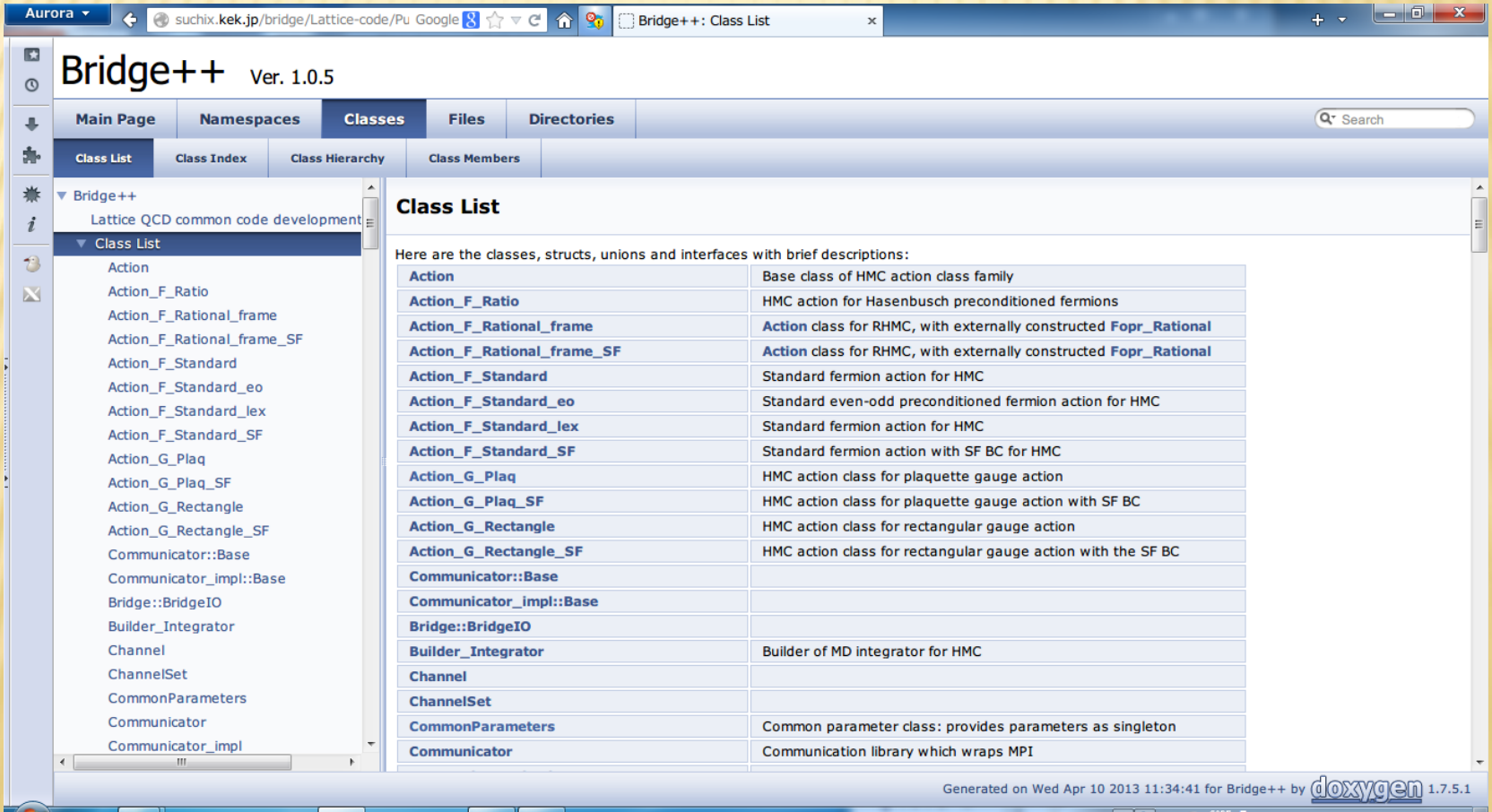
IMPLEMENTED FUNCTIONS

- 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
- Doxgen 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++'