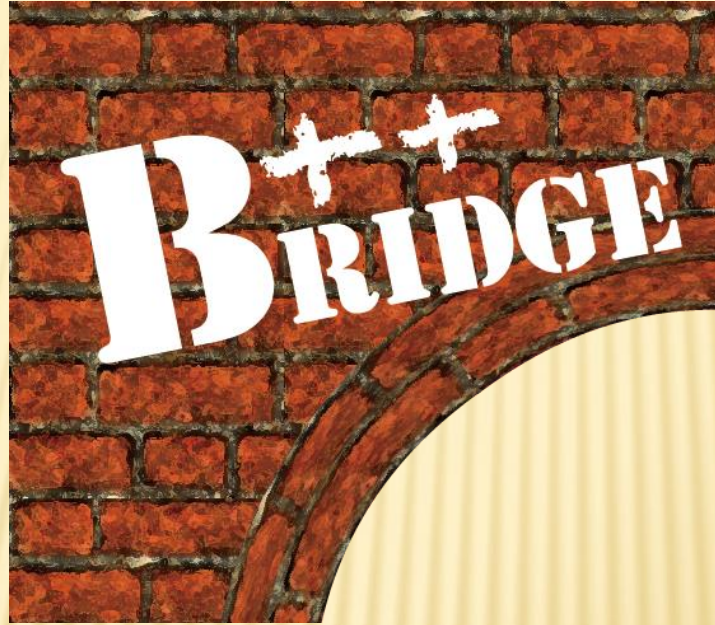


DEVELOPMENT OF AN OBJECT ORIENTED LATTICE QCD CODE "BRIDGE++"



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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/>
- ✦ 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

Perturbative calculation

- High energy region
- Deep Inelastic Scattering

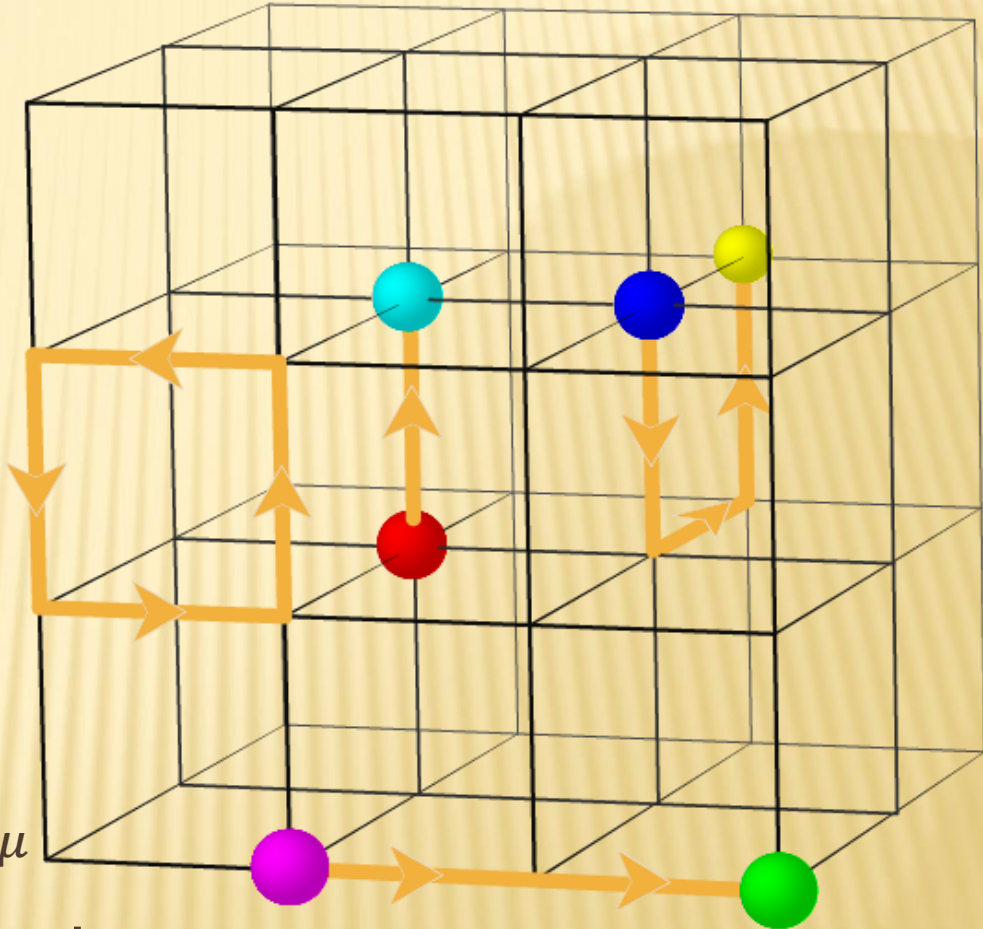
Non-perturbative calculation

- 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
 - $A_\mu(x) \rightarrow U_\mu(x) = e^{iA_\mu}$
- ✘ Action: gauge invariant
- ✘ Path integral quantization



OBSERVABLE IN LATTICE QCD

QCD: $\langle O \rangle = \int D\bar{\psi} D\psi DA_\mu O(\bar{\psi}, \psi, A_\mu) e^{iS_{QCD}}$

Wick rotation, discretization

Lattice QCD: $\langle O \rangle_{Lat} = \int D\bar{\psi} D\psi DU_\mu O(\bar{\psi}, \psi, U_\mu) e^{-S_{Lat}}$

Integrate Fermion part

$$\langle O \rangle = \int DU_\mu O(U_\mu) \det(D_F) e^{-S_G}$$

- In numerical Monte Carlo simulations:
- Generate gauge configurations under

$$P(U_\mu) \propto \det(D_F) e^{-S_G}.$$

- Expectation value $\langle O \rangle = \sum O(U_\mu)$.

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

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



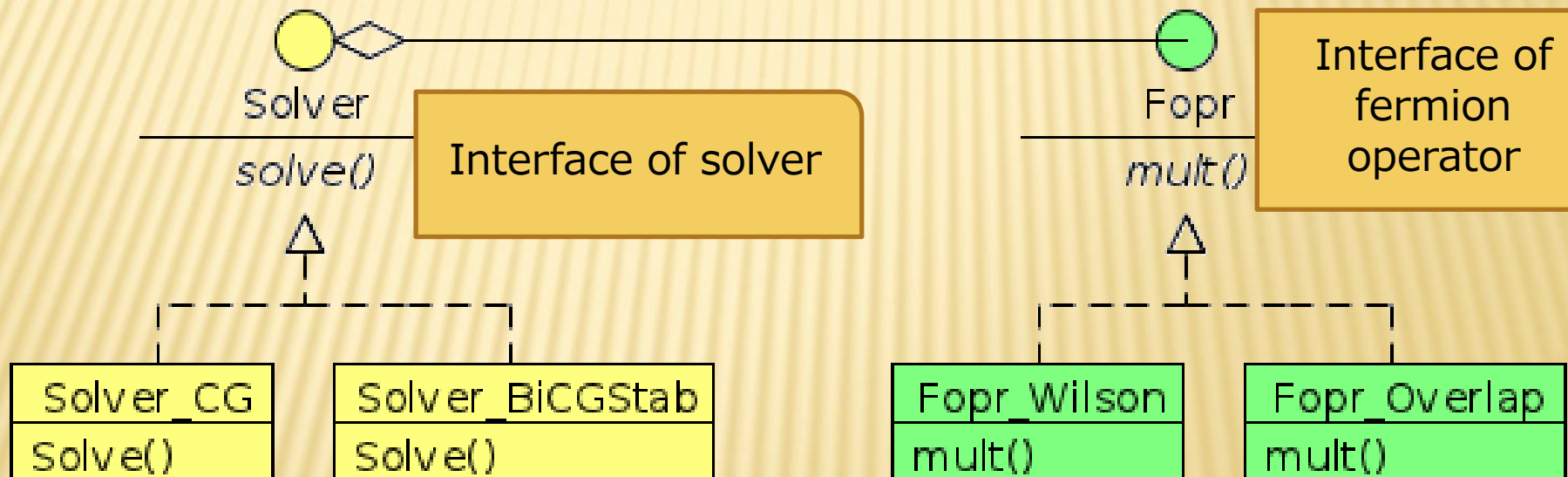
OBJECT ORIENTED

- ✘ 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.



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

The screenshot shows the Bridge++ Class List documentation page. The browser address bar shows the URL: `suchix.kek.jp/bridge/Lattice-code/Pu`. The page title is "Bridge++ Ver. 1.0.5". The navigation tabs include "Main Page", "Namespaces", "Classes", "Files", and "Directories". The "Classes" tab is active, and the "Class List" sub-tab is selected. The left sidebar shows a tree view of the class hierarchy under "Bridge++". The main content area displays a "Class List" with a brief description: "Here are the classes, structs, unions and interfaces with brief descriptions:". Below this, a table lists the classes and their descriptions.

Class List	
Here are the classes, structs, unions and interfaces with brief descriptions:	
Action	Base class of HMC action class family
Action_F_Ratio	HMC action for Hasenbusch preconditioned fermions
Action_F_Rational_frame	Action class for RHMC, with externally constructed Fopr_Rational
Action_F_Rational_frame_SF	Action class for RHMC, with externally constructed Fopr_Rational
Action_F_Standard	Standard fermion action for HMC
Action_F_Standard_eo	Standard even-odd preconditioned fermion action for HMC
Action_F_Standard_lex	Standard fermion action for HMC
Action_F_Standard_SF	Standard fermion action with SF BC for HMC
Action_G_Plaq	HMC action class for plaquette gauge action
Action_G_Plaq_SF	HMC action class for plaquette gauge action with SF BC
Action_G_Rectangle	HMC action class for rectangular gauge action
Action_G_Rectangle_SF	HMC action class for rectangular gauge action with the SF BC
Communicator::Base	
Communicator_impl::Base	
Bridge::BridgeIO	
Builder_Integrator	Builder of MD integrator for HMC
Channel	
ChannelSet	
CommonParameters	Common parameter class: provides parameters as singleton
Communicator	Communication library which wraps MPI

Generated on Wed Apr 10 2013 11:34:41 for Bridge++ by [doxygen](#) 1.7.5.1

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 Plaquette gauge action

Let's start lattice QCD with 'Bridge++'

