Recent Progress in Lattice Chiral Fermions

Particle Group

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M. Creutz & TM, PRD82 074502 (2010)
M. Creutz, T. Kimura, TM, JHEP1012 041 (2010)
M. Creutz, T. Kimura, TM, PoS Lat10 260 (2010)

YITP lunch seminar 04/27/11

Lattice Field Theory

~ 1st-principle study of Gauge theory ~

<u>Numerical study based on Monte-Carlo simulation</u>

Applied to LatticeQCD, Flavor physics, SUSY etc...

Peta-flops Computer is set now !! Still takes lots of time.....



RIKEN "KEI" in Kobe

◆ <u>Why expensive & What costs most ?</u>

$$\langle \pi_n \pi_m \rangle = \int \mathcal{D}U \det \underline{D}(U) e^{-S_G(U)} \operatorname{Tr}[\gamma_5 \underline{D}^{-1}(U)_{nm} \gamma_5 \underline{D}^{-1}(U)_{mn}] \\ \times \operatorname{Tr}[\gamma_5 \underline{D}^{-1}(U)_{nn}] \operatorname{Tr}[\gamma_5 \underline{D}^{-1}(U)_{mm}]$$

Quark propagator !

Fermion doubling problem

Fermions emerge with doublers on the lattice.

$$S_{\rm LF} = \frac{1}{2} \sum_{n,\mu} \bar{\psi}_n \gamma_\mu (\psi_{n+\mu} - \psi_{n-\mu}) \sim i \sum_\mu \gamma_\mu \sin(p_\mu) \qquad \begin{array}{c} 16 \text{ species in} \\ \text{Brillouin zone} \end{array}$$

◆ Nielsen-Ninomiya's no-go theorem

Chiral symmetry v.s. Absence of doublers

> 3 relevant quarks in QCD cannot be described.

♦ How to bypass the no-go theorem

Wilson, Staggered, Minimal-doubled, Domain-wall, Overlap...

No ideal fermion despite of long struggle



◆ <u>Remove 3 doublers</u> → <u>Rooting (Non-local)</u>





Rooting evil Less expensive







Less expensive





 g^2

4. Numerical tests

P. de Forcrand, et. al. (2011)



What is special

 Staggered Wilson & Overlap can make QCD simulation cheaper and faster. It will be a standard fermion in the future.

2. Staggered Overlap is another example of GW fermion, namely the pure theoretical solution for Doubling problem.

 $\sim (1 - \cos p_{\mu})$

$$\Gamma_{55} = (-1)^{n_1 + n_2 + n_3 + n_4},$$

$$\Gamma_5 = \eta_1 \eta_2 \eta_3 \eta_4 \sum_{\text{perm}} C_1 C_2 C_3 C_4$$

$$C_1 = \frac{1}{(V_1 + V_2)}$$

$$C_{\mu} = \frac{1}{2} (V_{\mu} + V_{-\mu}),$$