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論文題目：Data-driven construction of holographic QCD model

論文要旨：

The gauge/gravity correspondence is the duality between gauge theories and field theories on curved spacetime in one higher dimension. It has been studied as a crucial key to defining a quantum gravity. Despite its importance, a way to find a gravitational system dual to a given quantum field theory is not well understood. Particularly important quantum field theories are those with Yang-Mills sectors, including QCD, whose large N_c and strong coupling limit are believed to give a classical gravity dual. This class of gravity dual is called "holographic QCD". Although we are still lacking in how to construct the dual beyond the large N_c limit, inspired by such a class of correspondences, methodologies to describe QCD phenomena with field theories on curved background have been explored. Among them, the AdS/QCD models are field theories on asymptotic AdS spacetime which breaks conformal symmetry to describe the low energy physics of QCD. As a further development of the methodologies, improved holographic QCD is based on the five-dimensional Einstein-dilaton system with a non-trivial dilaton potential. Once a model of IHQCD is completely determined, we expect to learn fruitful lessons for how we can construct a gravity dual to a given quantum field theory, in which a clue of a quantum gravity is hidden. So phenomenological approach is an interesting and important direction for studying holographic QCD.

Since a holographic QCD model should be consistent with QCD, the construction of the model can be regarded as derivation of the appropriate model from experimental data. Previous works construct simple models with a few parameters, which are fixed from as many values as the parameters from the experimental data, but simple models are limited to show the agreement with the data far from the inputs. So, it is important to establish the way constructing a more complicated model.

To tackle such problem, we explore the data-driven framework to construct holographic QCD models. Our strategy consists of two steps in the construction.

The first step is the derivation of an AdS/QCD model, where bulk gravitational fields are treated as background ones. We proposed a deep learning method to build an AdS/QCD model from the data of hadron spectra. A large ambiguity is allowed for the bulk gravitational field with which QCD observables are holographically calculated. I adopt the experimentally measured spectra of ρ and a_2 mesons as training data, and perform supervised machine learning which determines concretely a metric and a dilaton field in the setup of the AdS/QCD model. The deep learning architecture is based on the AdS/DL correspondence where the deep neural network is identified with the emergent bulk spacetime.

The second step is derivation of an explicit form of the dilaton potential in improved holographic QCD from the above background fields obtained in the first step. We conduct the derivation with the ρ meson spectrum case and chiral condensate case, respectively. The former case is associated with a zero-temperature metric, and the latter data comes from the lattice calculation. Requiring that the gravitational fields are a solution to the Einstein-dilaton action derives the corresponding dilaton potential backward.

These derivations are the first example of the data-driven construction of IHQCD. In addition, these procedure enables us to obtain the metric and dilaton fields as the solutions to the Einstein equation. This ensures that the deep learning proposal is a consistent gravity. Furthermore, we find that the resulting dilaton potential satisfies the requirements normally imposed for IHQCD, and that the holographic Wilson loop for the derived model exhibits quark confinement at zero temperature. We show the usefulness of the model with the prediction at finite temperature that the string breaking distance is found to be consistent with another lattice QCD data.