# Research Plan

Nowadays the gauge/gravity correspondence (also called the AdS/CFT correspondence or holography) is a useful tool for understanding a strongly interaction theory in various research areas of physics and mathematics. They are, for example, not only particle theory but also information theory, condensed matter theory and so on. Since I have been studying various topics as I mentioned in "Research History", I shall engage myself in interdisciplinary researches. Here I should like to show some concrete topics that I am now interested in as follows.

**1. Quantum entanglement and string theory**

Quantum entanglement is a very intriguing phenomenon in quantum mechanics. Recently two geometric understandings of quantum entanglement from gravity theory have been proposed. One is the holographic derivation of entanglement entropy (EE) suggested by Ryu and Takayanagi in 2006. It allows us to calculate the EE from the area of a minimal surface embedded into a bulk theory. The other is the ER=EPR conjecture by Maldacena and Susskind in 2013. They have suggested that there exists an Einstein-Rosen bridge (or a wormhole) which connects an Einstein-Podolsky-Rosen pair.

- For examples supporting the ER=EPR conjecture, Jensen and Karch studied a pair of accelerating quark and anti-quark, and Seki and Sin studied a pair of scattering gluons. They showed the existence of wormholes on the metrics of the open string world-sheet which describe these pairs by the AdS/CFT correspondence. A natural question in order is how the change of entanglement of two particles are caused in a scattering process by interaction. Since the S-matrix theory is well-known for analyzing a scattering process, I should like to clarify the relation between the S-matrix and the EE in a quantum field theory. Furthermore, since both the scattering amplitude and the entanglement entropy are associated with minimal surfaces by the AdS/CFT correspondence, I should like to understand the change of EE in a scattering process from the geometric viewpoint of the minimal surfaces.

- What is the entanglement between two D-branes? A D-brane is regarded as a boundary state of a string, and we need to develop a way to apply a replica method for the system of D-branes in order to calculate their EE. It is also interesting to reconsider the tachyon condensation of D-brane and anti-D-brane in the context of the entanglement.

**2. Various applications of string theory**

- We know some intriguing relations between gravity and fluid dynamics. One is the black hole membrane paradigm. Emparan *et al.* have recently studied a black hole in the gravity theory with large $D$ dimensions, and Bhattacharyya *et al.* have suggested the membrane paradigm in this large $D$ gravity. The other is the fluid/gravity correspondence which was inspired in early 2000s by the gauge/gravity correspondence. In this context, many works on turbulence have been done. I should like to focus on the Burgers turbulence. Fouxon and Oz pointed out it in the gauge/gravity correspondence. Since the Burgers turbulence is relevant in large $D$ space, I shall consider it by the membrane paradigm in the large $D$ gravity and compare its result with what Fouxon and Oz obtained. Navier-Stokes equation is a long outstanding problem in mathematics as well as physics. This new approach would make progress in this problem.

- Last decade the gauge/gravity correspondence is applied to a variety of phenomena in condensed matter physics. This is called the AdS/CMT correspondence. However the condensed matter theorists say that this correspondence is currently useless to understand real materials. Therefore we should like to introduce to the AdS/CMT correspondence a kind of lattice structure which actual materials have. Since this requires to solve simultaneous second-order partial differential equations in the bulk gravity theory, we may need to rely on numerical computation. But it would contribute to the improvement of the AdS/CMT correspondence for the real condensed matter physics.