Summary of research

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My major research achievements are in quantum field theory, especially in the area of gradient flow equations. The gradient flow (GF) is a new analytical method to suppress the divergences in the quantum gauge field theory. This equation is a kind of diffusion equation, and the correlation function of the flow field, which is given by the solution to the equation, has the property of the UV finiteness.
This study focuses on the properties of the GF equation itself, which is the bases on the method of quantum field theory. In particular, we have studied the general non-perturbative properties of the GF equation and its extension to supersymmetry theory, and published related papers 2-5. In addition, We have published a paper 6 on the construction of GF for the supersymmetric Wess-Zumino model and the behavior of its solutions. Using the results, we proved that the supersymmetric flow theory with interactions is UV finite in all orders using the non-renormalization theorem, and published paper 8. As a phenomenological application of GF, We proposed a new method for finding sphaleron solutions, applied it to the SU(2) Higgs model, and presented paper 7. As a new application to quantum field theory, we proposed a new order parameter using the flow equation as a method to investigate the phase structure of spontaneous gauge symmetry breaking, and presented it in paper 9.

Especially, in Paper 2, we proposed a “generalized gradient flow equation” to make the GF method applicable to more general theories. The equation can be applied to not only the SU(N) Yang-Mills theory, but also the two-dimensional O(N) nonlinear sigma model and the supersymmetric Yang-Mills theory. This extension gives a general method to construct the flow equation without breaking the symmetry of the system. In particular, this paper focuses on the 4D N=1 supersymmetric Yang-Mills theory and derives the SUSY gradient flow equation keeping the explicit supersymmetry. This is the first application of GF to supersymmetry theory. In Paper 3, we constructed and analyzed the GF equation for a two-dimensional O(N) nonlinear sigma model. It is known that this model can be solved exactly in the large N limit. I found that the GF equation for this model becomes very simple in the large-N limit, and by solving this equation analytically, I showed that the two-point correlation function is finite without additional renormalization in a non-perturbative manner. This is the first non-perturbative demonstration of a property of GF that has only been shown perturbatively.