

Research Plan

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We want to establish new invariants of surface-links by means of biquandles and also to understand surface-links through these newly established invariants. We are trying to develop biquandle homology and cohomology theory much more and construct biquandle cocycle invariants for surface-links by means of marked graph diagrams and biquandle cocycles. Furthermore, I am planning to extend developed biquandle homology and cohomology theory and biquandle cocycle invariants to the case of virtual surface-links that are represented by marked graph diagrams including virtual crossings and are used to extend the notion of cobordism between classical links to the case of virtual links recently studied by L.H. Kauffman.

The main body of this research proposal is as follows.

- **Construction of flowed quandle cocycle invariants of surface-links.**

This is going to be done by using marked graph diagrams and certain kind of symmetric quandles introduced by A. Ishii to construct quandle cocycle invariants of spatial graphs.

- **Extension biquandles of quandles**

We are going to find a canonical way to obtain a biquandle from a given quandle, which is an extension of the quandle in some sense.

- **Biquandle cohomology and state-sum invariants of oriented links and surface-links**

In 2004, J.S. Carter, M. Elhamdadi and M. Saito introduced (co)homology theory for biquandles and state-sum invariants of oriented links by using cohomology theory for biquandles. By using the cohomology theory of biquandles, we will try to define biquandle cocycle invariants of oriented surface-links by means of both broken surface diagrams and marked graph diagrams, and then move to make generalizations to shadow versions.

- **Symmetric biquandle cocycle invariants of unoriented links and surface-links**

We first define symmetric biquandles and then develop corresponding symmetric biquandle (co)homology theory, which produces the intended symmetric biquandle cocycle invariants and their shadow versions.