Avatar: The Way of Hair, Cloth, and Coupled Simulation

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Figure 1: With one Solver Setup, we simulated every hero character's costume coupled with various surrounding environments. ©Disney.

ABSTRACT

This talk presents CreLoki, an extension to the multi-physics framework Loki. It enables unified creatures physics, such as hair and cloth in wet, dry, and underwater contexts with predefined coupling modes. By maintaining a solver setup configuration that is general enough for every foreseeable use case, CreLoki avoids the most tedious and error-prone steps of scene configuration. CreLoki also offers users a familiar interface via an Autodesk Maya plugin without compromising quality, customizability, or extendability. We found that this tool encourages a broader adoption of unified physics among creature artists.

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1 MOTIVATION

With quality and multi-physics interactions among the main design goals, the simulation framework Loki [Lesser et al. 2022] offers extraordinary versatility in simulating complex coupled scenes, enabling realistic hair and cloth behaviors in multiple major VFX productions. However, in creatures physics, the workflow can become heavy; it is not unusual to have hundreds of discrete elements (such as cloth or hair sets) in a typical creatures scene, along with settings for simulating coupled fluids. Generally, each simulated element and interactions between each pair would require a dedicated setup procedure, but this inevitably leads to an explosion of actions on the user side.

To overcome the challenge of tedious setups while still leveraging the power of coupling provided by Loki, we built CreLoki to serve as a simplified interface for creature artists. Specifically, CreLoki consists of three components: an Autodesk Maya plugin to wrap input elements and provide a familiar interface for artists; a Loki node graph to sort elements into categories (e.g., hair versus cloth); and a Loki Behavior tree that defines how elements in each of the categories should be simulated, including ambient fluid coupling settings. The latter two components are general enough to handle every use case in creatures physics and are reused for every scene regardless of its complexity. By freeing the users from thinking about Loki concepts and architecture while focusing on the scene, CreLoki was adopted quickly and contributed significantly to the production of *Avatar: The Way of Water* (see Figure 1).

2 GENERAL WORKFLOW OVERVIEW

Abstract Data Representation. Within Loki, each data object, such as a mesh or a set of curves, is wrapped inside a container called a *Scene Element*. A Scene Element includes a unique identifier, a set of tags, an optional data object, and collections of attributes. The multi-purpose attribute collections, called *Scene Element Components* (SECs), are used to specify properties on the object level, such as the Young's modulus of an elastic object, or to specify data channels for sub-object properties, e.g., per-vertex scaling of the elasticity. Simulation concepts such as attachments and collision settings are represented through Scene Elements without data objects, but with relevant SECs that reference other Scene Elements. See the supplemental document for more details on SECs.

User Interface. CreLoki's interface is implemented as a suite of custom Maya nodes. This includes one for Loki node graph evaluation; and several data conversion nodes that wrap data into Scene Elements, gather user parameters, and attach the appropriate SECs. See the supplemental document for examples. These conversion nodes are similar to those used by Maya's Nucleus, eliminating the need for users to learn new interfaces. Additionally, this approach allows users to quickly and procedurally set up scenes using Maya's scripting interface.

Loki Node Graph. Scene Elements are then bridged into a Loki node graph. When Scene Elements flow through the graph, they are grouped by types based on tags and sent into corresponding lanes for automatic assembling, before being pushed into the Solver Setup node (see Figure 2). Over time, we have built a monolithic, reusable Loki node graph that is general enough to host every creatures physics scenario encountered thus far.

Loki Behavior Tree. The Solver Setup node contains a Behavior tree that allows users to describe the desired physics without specifying detailed algorithms or the execution order. During simulation, each Behavior accepts Scene Elements from each data lane and selects the suitable algorithms to apply. Each is also responsible for dividing the algorithms into mutually compatible simulation stages and populating output Scene Elements, which are bridged back to Maya. See Lesser et al. [2022] for more discussion of Behaviors.

While the Behavior tree concept is highly configurable, in CreLoki we use a pre-built Solver Setup for all creatures scenes (see Figure 2).

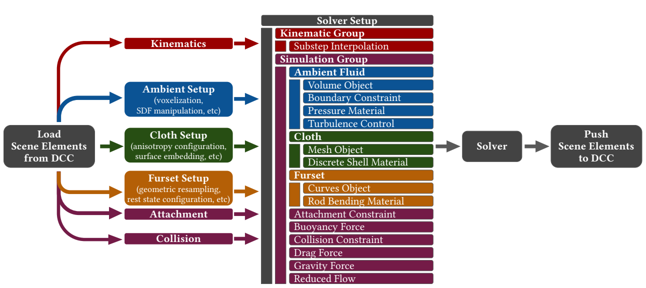

Figure 2: A single Loki node graph handles all possible data types, each wrapped in a Scene Element. Inside the Solver Setup, a Behavior tree is responsible for calling Loki solvers, which expect Scene Element Components to configure material properties and interaction relationships. ©Wētā FX.

Figure 3: Schematic view of how fluid voxels are allocated sparsely around elastic objects. ©Disney.

This frees the users from dealing with the Behavior hierarchy and allows the developers to continuously extend the tools on the leaf level without touching other parts of the tree.

3 COUPLING

The coupling of cloth and hair with the surrounding ambient fluids closely follows [Stomakhin et al. 2020; Wretborn et al. 2022]. As illustrated in Figure 3, fluid grids are allocated sparsely around each elastic object. In each time step, we use Newton's method and alternate between the implicit solids solver that considers the presence of the fluid drag and buoyancy forces, and the fluid's Poisson solver which accounts for the negated drag force and solids as kinematic boundaries. The border of the sparse fluid domain enforces a combination of (typically hydrostatic) pressure and velocity boundary conditions in order to blend with the background wind or current. For more details, please refer to the supplemental document.

4 CONCLUSION

We presented CreLoki, a toolkit that integrates Loki, the latest multi-physics simulation framework, into our creatures production environment. CreLoki not only inherits the high-quality Loki solvers with excellent coupling capability, but also eases the setup procedure with customizable materials and interactions. We believe that the proposed workflow is an important extension to Loki as it has been adopted and preferred in many major VFX productions over time, especially *Avatar: The Way of Water*.

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