JoinUS: Gliederung der Ausschreibung

About Us: At LWW, our pioneering research is driven by a passion to understand the complex interactions between water and sediment in fluvial ecosystems and their inhabitants. From sediment erosion to river restoration to flood protection, our work has a direct impact on natural and human-made infrastructure. Join us as we strive to achieve a balance between ecological sustainability and hydraulic demands, employing cutting-edge field and computer technology to leverage data insights with mathematical models and AI.

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Research group / department: Department of Hydraulic Engineering and Water Resources Management (LWW), Institute for Modelling Hydraulics and Environmental Systems (IWS)

Revolutionize Computational Hydraulics with Data-Driven Models and Video Engines

Keywords: Numerical modeling, smoothed-particle hydrodynamics, machine learning, rivers, ecohydraulics

Introduction / Background

Are you ready to dive into the forefront of hydraulic engineering? In this project, the successful candidate will advance cutting-edge research tools in river hydraulics to a new level of excellence. State-of-the-art modeling of hydrodynamics builds on two-dimensional (2d) depth-averaged models and three-dimensional (3d) numerical modeling of potentially large landscapes. In this process, complex hydrodynamic equations are typically solved across a numerical grid, which necessitates ample simplifications. For instance, processes occurring between grid nodes, such as the dynamics of turbulent eddies that are smaller than the grid, are interpolated based on Gaussian statistics. However, the world does not follow normal distributions, and extreme value statistics govern our environment. This is why the so-called Reynolds averaging, which uses a mean and standard deviation (i.e., Gaussian statistics) to approximate turbulence properties, leads to high imprecision. Grid-based numerical solvers can address this inaccuracy through extremely high grid resolution but at a high computational cost.

Recent developments in video engine development and machine learning offer options to circumvent the high-cost computations of grid-based models, making them attractive for this project. Particle-based simulations in video engines will be employed as they are computationally more efficient through massive parallelization. They also allow for the emulation of interactions between entities like fish and water, fish provides revolutionary new visions for ecohydraulic modeling.

The mission of this Ph.D. project is to develop and compare computationally efficient 3d numerical modeling schemes within video engines and place virtual actors like fish with specific behavior that can be emulate, for example, with neural networks.

References

- Gingold & Monaghan, Smoothed particle hydrodynamics: theory and application to non-spherical stars, Mon. Not. Astr. Soc. 181(3), 375–389, 1977, doi: 10.1093/mnras/181.3.375.
- Franca & Brocchini, Turbulence in Rivers, Rivers – Physical, Fluvial and Environmental Processes, Rowiński & Radecki-Pawlik (Eds.). Springer Int. Publishing, 2015, 51–78. doi: 10.1007/978-3-319-17719-9_2.
- Programming and modeling tutorials: https://hydro-informatics.com
- Niagara Fluid: https://docs.unrealengine.com/5.1/en-US/niagara-fluids-quick-start-guide-for-unreal-engine/

Your Tasks:

- Familiarize with state-of-the-art numerical modelling of rivers, Python programming, and data analysis using AI.
- Potential participation at field surveys for data acquisitions.
- Familiarize with Unreal Engine and it fluid simulation plugins.
- Build numerical video game engine models that account for fish presence.

Research goals

The Ph.D. candidate will familiarize with existing grid-based open-source 3d numerical modeling (CFD) software and novel particle techniques. Study materials, guidance for model calibration and validation concepts, and in-house machine learning (data-driven) algorithms will be provided. Particle-based methods will be applied through the Houdini and Niagara fluid plugins of the Unreal Engine, enabling a radical rethinking of numerical modeling in hydraulic engineering through massive parallelization and interactive exploration of simulation results.

Methods to be used

First, a grid-based model will be set up using existing data for a real-world environment (the data is already available). Second, a grid-based model will be build, and potentially combined with data-driven sub-models. Next, a particle-based model of the same structure will be created using a virtual video engine (Unreal Engine) and a fluid-implicit particle method (Niagara fluid and Houdini plugins). Comparing the computing time between grid-based models and particle-based methods will benchmark the first fundamental research achievement.

Ultimately, the virtual (Unreal) world will be populated with typical fish characters to quantify the flow field and identify preferable ecohydraulic conditions. This second fundamental achievement is expected by enabling fish-water interactions and adding behavioral rules through algorithms like neural networks or decision trees. Thus, one of the first fully functional ethohydraulic models will represent ground-breaking research progress and conclude a Ph.D. thesis with global impact.

Your Profile:

The ideal Ph.D. candidate for this project should possess a robust background in hydraulic engineering, computational fluid dynamics (CFD), and/or environmental engineering. They should have accomplished courses in numerical modelling.

The candidate should also have interest in machine learning algorithms and their application in enhancing computational models. Proficiency in programming languages such as Python or C++ is not required, but their knowledge in the context of data analysis and numerical modelling is a plus. Additionally, the candidate should have experience or a keen interest in using virtual video engines like Houdini or Unreal Engine and its Niagara fluid plugin.

A solid academic background with a Master's degree in hydraulic engineering, mechanical engineering, simulation technology, environmental engineering, or a closely related field is necessary. Strong analytical skills, the ability to work independently and collaboratively, and effective communication skills for presenting complex technical information are also important attributes for this role.

Prerequisites

Your Benefits: Join a highly skilled team with extensive experience in cutting-edge technology. Take advantage of networking and mentorship events, and enjoy special offers for PhD students.

Research Environment

The Ph.D. candidate will have their own shared office (2-3 students per office) and run computer models on clusters and PCs at IWS. Optionally, participation in fieldwork surveys can be conducted to enrich the available data for model optimization. The successful candidate will be part of an interdisciplinary working group focusing on fluvial hydro-morphodynamic processes in conjecture with ecohydraulics of freshwater environments.